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# AN ANALYSES OF WIND DATA GATHERED AT NINE MONITORING SITES IN MONTANA

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# AN ANALYSES OF WIND DATA GATHERED AT NINE MONITORING SITES IN MONTANA

Prepared by

Gunderson Consulting Service
525 East Davis Street
Bozeman, Montana 59715

July 1984

Prepared for

Montana Department of Natural Resources and Conservation
1520 East 6th Avenue, Helena, Montana 59620
Renewable Energy and Conservation Program
Grant Agreement Number RAE-82-1016

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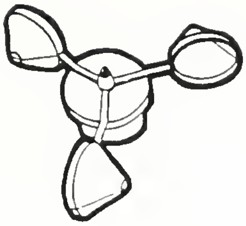

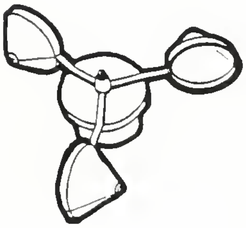

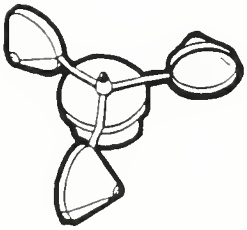

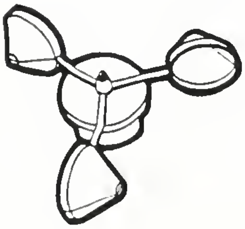

# ERROR ANALYSIS
# for
# Data Gathering and Processing

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
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# ERROR ANALYSIS REPORT FOR ANEMOMETER LOAN PROGRAM
(Grant #82-1016)
for
DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

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Both Charless Fowlkes and John Obermeier contributed expert advice which greatly added to the quality and accuracy of the material in this report.

## Description of Equipment

Natural Power Inc., New Boston, New Hampshire, manufactured the all three types of data recorders used to gather the wind data. Two of three data recorders were strip chart recorders. The third type of recorder is called a wind spectrum analyzer or compilator.

Both types of strip chart recorders are essentially identical. The only difference being that one model recorded wind speed as well as direction (a dual channel recorder) while the other recorded only wind speed (single channel recorder). Each monitoring system is composed of a data recorder, a 4-pole cup anemometer, direction sensor (only dual channel recorder systems), a 12-volt wet cell automobile battery, and all the cable needed to connect the sensor(s) to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system is an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operating specifications for the strip chart recorders are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The strip chart recorders record a wind speed reading every two seconds by making a mark on the strip chart. To make the mark, an impact bar strikes the top side of the meter needle, which then touches pressure-sensitive paper (a "strip chart") moving slowly beneath the needle. These dots accumulate on the moving paper forming a graph of the wind speed.

The compilator system, includes: a Series A30 low-temperature data compilator ("Compilator I"); a model A75-104 four-pole cup anemometer; a 12-volt wet cell automobile battery, and the cables needed to connect the sensor to the Compilator, the Compilator to the battery and the entire system to a grounding stake. Completing this system is an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operating specifications for the Series A30 Compilator I are:
Temperature range: -40 to 70 degrees C.
Recorder accuracy: + or - 1%
Compilator clock: + or - 15 minutes/month
Response time: 1 second

The Compilator I separates wind speeds of 0 to 62 MPH into thirty-one discrete increments of 2 MPH each (speeds of 62 MPH or more are grouped together into the thirty-second increment) then counts and stores the number of seconds the wind speed is blowing in each increment. Periodically, the site owner copies the stored information from a digital display in the front panel onto a data log and erases the compilator memory so it can accumulate fresh data.

The operating specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operating specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH

Temperature range -60 to 200 degrees F.

The tower is a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Description of the Data Analysis Procedure

I. Strip Chart Analysis - Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the hourly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The site readings were extrapolated to the sensor height of the NCC station. Finally the adjusted site three-hourly average speed was divided by the weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

II Compilator Analysis - The data for each reading period was entered into the computer and stored in a data file on a 5.25 inch floppy disk. Using this data, another program calculated the average wind speed for each reading period and for the entire monitoring period. To minimize erors in averaging the monitoring period speed, separate running totals were maintained for each of the compilator's 32 wind speed brackets or "bins".

From the data in the bins, a wind speed percentage spectrum was calculated by adding together the contents of a single bin or several bins, then dividing that total by the total of all 32 bins. This calculation produces the percent of time the wind blew in each percentage spectrum bracket during a reading period. The sizes of the wind speed percentage brackets were set to fit the performance of most wind generators, just as the brackets werp set for the strip chart data.

Next, the computer used the wind speed averages to calculate wind power density values for each reading period and the entire monitoring period. Note that these values cannot be a very acurate description of the wind power potential at the site, since they result from long-term (greater than 1 hour in length) wind speed averages. The longer the time period of wind speed average used in calculating wind power density, the more unreliable the value generated is. A more detailed description of the calculation of wind power density will follow later.

The anemometer height difference and wind speeds for corresponding time periods from the two locations were then used to corelate data from the monitoring site with data from the nearest National Weather Service Station. The height difference was adjusted using the "1/7 power law" as previously described.

The time lag in weather between the site and the weather service station is corrected for in the nature of the recorded data. Since the compilator reading periods are much longer than the weather time lag between the site and the weather service station, this effect can generally be ignored. When a reading period is of the same order of magnitude as the weather time lag, the resulting correction value is not accurate. This is rarely the case however.

To calculate the wind speed correlation factors between the site and the weather service station, the three-hourly average readings from the weather service station, corresoponding to each compilator reading period, were extrapolated to a sensor height of 10 meters. Then, the average speed at the site was divided by the extrapolated average speed for the weather station to obtain the average correlation value for each reding period. To minimize averaging errors, separate running totals were maintained when calculating the average monitoring period correlation factor.

The final level of data analysis for both the strip chart and the compilator data was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station. To project wind speed, three-hourly average speed data from the weather station is multiplied by the monitoring period correlation factor, then extrapolated to an elevation of 10 meters, and lastly is averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three-hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. Wind power density is defined as:

$$P= (1/2)\rho KV^{3}$$

where $P$ = wind power density
$\rho$ = air density
$V$ = wind speed
$K$ = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density $\rho$ is defined as: $\rho = A/(RT)$

where $A$ = atmospheric pressure
$R$ = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
$T$ = absolute air temperature in degrees Kelvin.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

## Error Analysis

The calculated, estimated and inferred percentage error bandwidth for both the strip chart and compilator wind speed is about + or - 15%. This error rating includes data gathering, analysis and projection. The monitored data show that the projected speeds for the seven monitored sites (no projections were made for 2 sites that had abnormal correlation factor curves) are valid for 16 out of 20 months, or 80% of the time.

The calculated, estimated and inferred percentage error bandwidth for strip chart and compilator wind power density is about + or - 25%. The monitored data with this error bandwidth correspond to the projected wind power density values at the seven monitored sites in 14 out of 20 months, or 70% of the time.

For the following discussion several terms need to be defined. The absolute error of a number, measurement or calculation is the numerical difference between the true value of the quantity and its approximate value as given or obtained by measurement or calculation. The relative error is the absolute error divided by the true value of the quantity. The percentage error is 100 times the relative error.

For the purpose of this discussion, the total error in gathering and processing DNRC's wind data is divided into three parts: gathering, analyzing and projecting. Error in data gathering results from the nature of the instrumentation used to record the data and from the manner in which the site owners operated it. Analysis error results from the equipment used to transform the wind data from the recorders into numerical data stored in computer memory and from the equations used to convert the numerical data into printed averages for the monitoring period. Lastly, projection error results from correlating the monitored data with nearby NCC data and then projecting minimum, maximum and average wind years at the monitoring sites.

The error from data gathering is obtained from the instrument specifications plus an estimate made for site owner operation. Data analysis error comes from a variety of sources: data transcription, analysis technique, and roundoff. Each presents a level of error that may be measured or calculated. Projection error must be inferred since I cannot and I have no references that show how to reliably estimate or calculate the error resulting from anemometer height projection or the correlation and projection of the mean, maximum and minimum wind years for sites monitored for short periods of time (less than several years). I inferred this component of the total error using the percentage errors between the monitored site data and the projected data's bandwidths.

I. Gathering Error - The wind speed sensor used is very accurate for wind speeds greater than 3 MPH. Since the wind regime of interest for wind power surveys is greater than 10 MPH the sensor used is satisfactory. Error from the speed sensor not responding to peak wind gusts is generally balanced by the tendancy of the rotating cups to gradually slow after a gust.

The largest amount of error from the strip chart recorders results from variable motor speed caused mainly by change in the ambient air temperature. The analysis technique we used corrects for speed variation over the time between site owner's notation of the time and date on the strip charts. The more frequent and thorough a site owner was at noting the time and date on strip charts, the greater the accuracy of the data gathering. I feel the errors introduced by recorder motor speed variation generally cancel each other. Since the analysis programs correct the overall speed variation, the error when the motor runs faster than average (day time) will cancel the periods it runs slower (night time). A value for sensor and recorder error cannot be calculated but I estimate the sensor-recorder error to be less than + or - 5%.

The strip chart recorders do not graph wind speed on a linear scale. This nonlinear responce was fully corrected for in the analysis software. For a more detailed discussion of the correction technique the reader is directed to the strip chart analysis software reports for this project.

II. Analysis Error - Data transcription errors using the compilator monitoring system were eliminated by verifying that the number of seconds recorded by the compilator between each reading period correspond to the time elapsed between readings. When a discrepency was discovered, we discarded the reading.

Transcription error of strip chart data is dependent on the ability of the digitizer operator to accurately and repeatedly digitize a segment of strip chart to obtain nearly an identical average wind speed. The operators use three averages calculated by the computer, the largest and smallest digitized y-coordinate for the segment, the number of coordinate pairs digitized and an exact scaled graph of the digitized data plotted by the printer to decide on the digitizing quality of a segment.To test digitizing accuracy, the operators repeatedly digitized a test pattern (7 times during a 6 month period) having an average wind speed of 12.29 ± .33 MPH. The test resulted in a percentage error of + or - 2.69%. This error increases as the average wind speed decreases and, decreases as the speed increases. For example, on a similiar test plot (repeated 4 times) with an average wind speed of 5.75 ± .47 MPH, the percentage error rises to + or - 8.17%. Since the average wind speed of most of the sites was closer to 12.29 MPH (usually higher), I used the + or - 2.69% value in the error calculations that follow.

The equation used to compute the wind power density provides the majority of the data analysis error for calculating the wind power density. Obtaining the differential error expression from the wind power density equation yields:

$$\frac{\Delta P}{P} = \frac{\Delta A}{A} + \frac{3V^2\Delta V}{V^3} - \frac{\Delta T}{T} = \left|\frac{1.7}{887.8}\right| + \left|\frac{3(.33)}{12.29}\right| + \left|\frac{6.67}{280.21}\right| = .1063 = + \text{ or } - 10.63\%$$

where P - wind power density in watts/square meter
A - air pressure in millibars
V - wind speed in MPH
T - average monthly air temperature in absolute Kelvin degrees.

The absolute error for the absolute temperature was derived using the 30-year yearly average maximum, minimum and mean ambient temperature for Great Falls. The average differential was 11.85 degrees F or about 6.67 degrees absolute. The yearly average temperaure being 44.7 degrees F or 280.21 degrees absolute.

The absolute error for air pressure was derived in essentially the same manner. The yearly maximum and minimum pressures were selected from the 30-year monthly averages.

Averaging digitized wind speed into hourly average wind speed values also adds analysis error in calculating wind power density. The hourly average wind speeds are used to calculate wind power density rather than summing and averaging a wind power density value for each individual digitized speed value. Since wind power density is proportional to the cube of wind speed, any error in wind speed (through averaging) will be greatly magnified. Three months of digitized data from a site results in storing about 1.13 million xy-coordinate pairs or about 87 data elements per inch of strip chart. Assuming an average wind speed of 12.29 MPH and a uniform distribution of data points varying in y-coordinate value of less than .5 inch per 1 inch variation of x-coordinate value, the percentage error in wind power density calculation is + or - .04%, i.e., 1858.4 compared to 1857.63 watts/M2. As the average wind speed is increased the error drops and as the speed decreases the error increases. At 20 MPH the error decreases to + or - .02% and at 5.75 MPH the error rises to + or - .18%. Thus using 1 hour average wind speeds to calculate wind power density results in an acceptable cost in error. I use the value obtained at an average wind speed of 12.29 MPH in calculating the total error.

The last source of analysis error in calculating wind power density and wind speed results from rounding error in data sums in the computer. The operating system that implements BASIC on the 69A central processing unit represents decimals with a 7 byte (56 bit) signed mantissa and a single byte excess 128 notation exponent which translates into a 17 decimal digit mantissa. The system's round off algorithm is an industry standard resulting in errors due to rounding being largely neutralized. Thus I consider rounding to introduce no significant amount of error into the type of calculations used in this study.

III. Projection Error - As mentioned before, the amount of error introduced in projecting the mean, maximum and minimum wind years at a site cannot be calculated directly. Comparing monitored wind speeds to the projections for each site made from long-term weather service data allows the error from the projections to be inferred.

In the following discussion the term, correspondence ratio, is used. A correspondence ratio tells what percent of the monitored data corresponds to or falls within the projected data range given the stated error tolerance. For example, given the data: 10, 12 and 18 for the November, December and January monthly average wind speeds with a percentage error rate of + or - 10% and the projected data ranges of 8-9, 14-16, and 17-20 for these months, the correspondence ratio is 2/3 or 67%. Note 10 ± 10% = 9 to 11 falls within the range 8-9, 12 ± 10% = 10.8 to 13.2 does not fall within the range 14-16, and 18 ± 10% = 16.2 to 19.8 falls within the 14-16 range. The closer the correspondence ratio is to 100%, the better the monitored data corresponds to the projected data within the given error tolerance.

By inferring an error of 7% for strip chart wind speed projection, 12 of 15 valid, fully monitored, monthly wind speeds fall within the projected monthly wind speed bandwidths, i.e., a correspondence ratio of 80%. This implies that using three-hourly average wind speeds to calculate the site/weather station correlation factors at strip chart sites is a reliable element in the software system.

Inferring a projection error of 9% for wind power density for the strip chart systems results in a correspondence ratio of 67% between the monitored and the projected wind power density values. In other words, 10 out of 15 months of monitored data correspond to the projections given the total error bandwidth of + or - 25%. As expected, small errors in projected wind speed result in large errors in wind power density.

Though the compilator, as a data recorder, is much more accurate than a strip chart recorder, using long-term (5-90 days) average wind speeds to calculate the site/weather station correlation factor introduces enough additional error so the total error rate for both types of recorders is the same. If I assume the compilator's projection error rate is 14%, the correspondance ratio is 80%, i.e., the same as that for the strip chart systems.

The wind power density values obtained from the monitored data corresponded much better to the projected monthly values for the compilator than for the strip chart systems. When I assumed a 13% projection error rate, an 80% correspondence ratio results between the monitored data and the projected data. Given the small sample size (1 site or 5 months of valid monitored data) this is not a reliable estimate. If DNRC uses the compilator system to monitor sites in the future, this figure should be re-evaluated using the larger sample size.

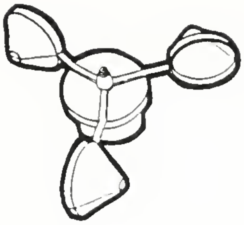
In summary, the amount of error for wind speed using a strip chart system results in an average percentage error band of + or - 15%. In detail: recorder error (5%) plus analysis error (2.69%) plus the inferred projection error (7%). For wind power density, the average error bandwidth is + or - 25%: recorder error (5%) plus total analysis error (10.63% + .04%) plus the inferred projection error (9%).

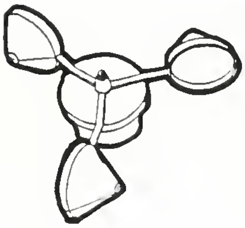
The amount of error for wind speed using a compilator system is also + or - 15%, i.e., recorder error (1% from manufacturer) plus analysis error (0%) plus inferred projection error (14%). For wind power density for the compilator system, the error bandwidth is + or - 25%, i.e., 1% recorder error plus 11% analysis error plus 13% inferred projection error.

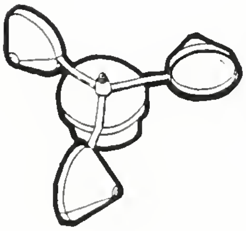
In conclusion, for obtaining wind speed, the estimated data gathering, analysis and projection percentage error rate for both types of recording systems used in DNRC's Wind Anemometer Loan Program, is + or - 15%. In total, 16 of the 20 full months of monitored data (80% of the time) fell within the projected results for the 7 monitored sites.

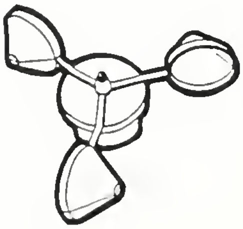
Projecting the mean, maximum and minimum wind power density years for the sites resulted in an error bandwidth of + or - 25% for both recorder types. Here

14 of the 20 full months, a correspondence ratio of 70%, fell within the projected results.









# Survey of Wind Power
# at
# The Sieben Livestock Co., Cascade, MT

October 19, 1981 - June 2, 1982

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring systems DSR-#1 and DSR-#2 at the Sieben Livestock Co. ranch near Cascade, Montana from October 19, 1981 to June 3, 1982.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensors used in the system which gathered this data. The system includes: a model A11-132 dual strip chart recorder housed inside a model A95-003 plastic case; a model A75-104 4-pole cup anemometer; a model A75-301 wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensors to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operational specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operational specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH
Temperature range -60 to 200 degrees F.

The operational specifications for the model A11-132 strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The strip chart recorder records a wind speed and direction reading every two seconds by making a mark on the pressure sensitive strip chart paper as it crosses a metal plate. To make the mark, an impact bar strikes the top side of the meter needles, one for wind speed and one for wind direction, which then touch the sensitive paper.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On October 18, 1981, under Renewable Energy Grant Agreement #220-800, Gunderson Consulting installed wind monitoring system #DSR-1 at the Sieben Livestock Co. ranch near Cascade, Montana. After installation, Whit Hibbard conducted the study on his own. In June, 1982, he dismantled the monitoring system, returned it to the Department and delivered the filled strip charts to Gunderson Consulting to be processed and analyzed as a part of this project (Renewable Energy Grant #82-1016).

To locate the monitoring site, travel south from Cascade on State Route 330 for six miles to a large sheep shed on the east side of the road atop a hill. Turn west onto a gravel road and proceed for 28-29 miles to the ranch.

The reader will find several gaps in data during the monitoring period. The gap from 11/22/81 to 11/29/81 occurred when the battery was discharged. The five-month gap from 12/15/81 to 5/18/82 results from our decision to exclude the data recorded by DSR-#1 during that period. The data recorded from 12/15/81 to 5/18/82 looks legitimate on the strip charts, but when it is analyzed and then compared to data recorded during the same period at the NCC station data, it is clear that, as the site owner suspected, DSR-#1 was malfuncitoning. Therefore, those strip charts were excluded from this study.

Concerned about the validity of the data being recorded by DSR-#1, Mr. Hibbard consulted the Department engineer and myself, and borrowed a different recorder (DSR-#2) from the Department. DSR-#2 produced valid data and Mr. Hibbard continued the study until June 3, 1982.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computed calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

The weekly and monthly wind direction summaries were prepared manually from the marks made by the wind direction needle on the eight direction tracks on strip chart. (One track on the strip chart is assigned to each octant of the compass--N, NE, E, SE, etc.). For each summary period, the operator counted the number of quarter-inch (15-minute) marks in each direction track on the strip chart at the same time he digitized the wind speed curve. He then divided the total number of marks in each direction track by the total number of marks in all direction tracks during the same period to derive the percentage of time the wind blew in each octant for the summary period.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Great Falls) is at 6.7 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station at Gore Hill in Great Falls. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three- hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most

useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P = (1/2)pkV^3$$

where P = wind power density
p = air density
V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density p is defined as: p = A/(RT)

where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## Data Use

First, refer to Appendix I and compare the average wind power density at your monitored site to the densities at other sites in the state. (Comparison of wind power densities provides the best picture of how one site's potential compares with others.)

Next, estimate the power output you might expect from a particular wind generator installed at your site. You will need the generator manufacturer's wind-speed-versus-power output graph, or "power characteristic curve' as it is sometimes called (Appendix II is such a curve for a Holec Windmatic model 14S wind generator), and the 'Average Monthly and Yearly Wind Speed and Percentage Speed Profile" of your site. Follow the procedure in the example below to estimate yearly (or monthly) generator ouput. Then, to calculate a dollar value of the power that generator might generate under the conditions at your site, multiply the estimated generator output by the value of the electricity you would be displacing.

In the following example use the Power Characteristic Curve in Appendix II and the following annual wind speed percentage spectrum:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these annual percentage figures into the number of hours per year the wind blew in each bracket. Multiply the percent value from the percentage spectrum by the number of hours in a year, (365 X 24 = 8,760 hours in a year). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds in the less-than-10-MPH bracket. For the second bracket, the wind blew .05 X 8,760 = 438 hours at speeds between 10 and 10.99 MPH. This process can be continued for each bracket of the spectrum. The final result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

The next step is to assign a MPH value to the middle of each velocity bracket and then use the Power Characteristic Curve to find the generator's power output for each associated midpoint speed. The midpoint of each velocity bracket has been rounded to the nearest MPH for convenience below.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KW) FROM POWER CHARACTERISTIC CURVE

To do the final step, multiply the number of hours in each bracket by the generator output and add all of the ouputs together to obtain the total generator output for the period, which, in this example, is one year.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

In this example, the generator output for the total period (one year) is 51,771 KWh. To find the value of the electricity which would theoretically be displaced by this generator at a site with this wind speed profile, multiply the value of the electricity by the total production. In this example we will use $.0625/KWh for the unit value of displaced electricity; therefore, the total value of the displaced electricity would be $3,235.69 per year.

However, many factors other than the cost of the generator and the value of displaced electricity must be considered to make a realistic evaluation of the economics of wind electric generation at your site--factors such as: the one-time costs of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for the foundation, freight charges, fees for inspection and system checkout, and the continuous expenses of insurance, operation and maintenance. The following breakdown gives a broad guideline for the cost of a larges scale wind development:

Generator and Blade Assembly - 57%
Tower and Site Access - 11%
Foundation/Site Preparation - 9%
Operations/Maintenance - 9%
Assembly/Checkout - 8%
Other - 4%
Equipment Transportation - 2%

Source: from publication SERI/SP-732-728 pulblished by the Solar Energy Research Institute, October 1980.

Not all of these costs will apply in the same percentages to every installation, but the likelihood is always a good that other costs will occur in their place.

As a rule of thumb, a wind site that has a wind power density of over 200 watts per square meter and has a minimum average wind speed of 12 MPH for at least six months per year should considered for wind development. The final decision to develop your wind potential is an investment decision which deserves the same degree of careful analysis as you give any other development investment. Appendix III is a suggested wind electric generation development guide.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

The multi-page summary titled "Wind Speed Summary (in MPH) and Percentage Spectrum" contains daily, weekly and monthly average wind speeds and a wind speed percentage spectrum for each speed average. This summary should be interpreted in the same manner as the preceeding summary.

On the summary sheet titled, "Weekly and Monthly Average Wind Power Density," the last column gives the weekly and monthly average wind power density at the site during the monitoring period. The average wind speed in mph is also shown.

The summary sheet titled, "Weekly & Monthly Wind Direction Profile," gives the approximate percent of time the wind was blowing in each of the 8 different compass directions during the monitoring period. (Please note that these directions are based on magnetic North, not geographic North.)

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors" for each time period, which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these

sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But while the preceeding summaries estimate wind power density, these estimate wind speed averages--the mean, minimum and maximum monthly and yearly average wind speeds likely to occur at the site--and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

```
PAGE 1

              WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  CASCADE                  TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:  10/19/81

                                              PERCENTAGE WIND SPEED PROFILE
 DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
----------------------------------------------------------------------------------------------
  19     * 9.0  7 HRS   57  14   0  14  14   0   0   0   0   0   0   0   0   0   0   0   0   0
  20       5.6         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  21       5.7          96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  22       6.3          83   4   0   0   0   8   4   0   0   0   0   0   0   0   0   0   0   0
  23       6.7          71  13   8   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0
  24      10.2          71   0   4   0   0   0   4   8   4   0   8   0   0   0   0   0   0   0

WKLY  AVG=>  7.2        83   5   2   2   2   2   2   2   1   0   2   0   0   0   0   0   0   0

  25      22.8           0   0   0   0   0   8   4  25  17   8   4  21   0   8   4   0   0   0
  26      12.7          38   4  13   4   0   4  17  13   4   4   0   0   0   0   0   0   0   0
  27       7.7          71   4   0   4   8  13   0   0   0   0   0   0   0   0   0   0   0   0
  28      11.0          33   4   8  29   4  17   4   0   0   0   0   0   0   0   0   0   0   0
  29       9.5          58   8   8  13  13   0   0   0   0   0   0   0   0   0   0   0   0   0
  30      18.8           0   0   4   8   0  17  25  17  13   0   4   4   4   4   0   0   0   0
  31      18.1          17   4   0   0   8  13   8   4  13  13   8   8   0   4   0   0   0   0

WKLY  AVG=> 14.4        31   4   5   8   5  10   8   8   7   4   2   5   1   2   1   0   0   0

----------------------------------------------------------------------------------------------
 OCT      11.1          53   4   4   5   3   6   5   5   4   2   2   3   0   1   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  0000 HOURS
STARTING DATE:  11/ 1/81

                                                 PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
   1         8.0         75  13   0   4   4   0   4   0   0   0   0   0   0   0   0   0   0   0
   2         7.9         88   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   3         9.7         58   8   8   0   0  17   0   0   8   0   0   0   0   0   0   0   0   0
   4         6.9         79   8   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   5         6.8         83   4   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   6        14.0          4  21  25   4  13   4  13   4   8   4   0   0   0   0   0   0   0   0
   7        12.5         50   4   4   0   4   8   0   0   4   4  17   0   4   0   0   0   0   0

WKLY  AVG=>  9.4         63   9   8   3   3   4   2   1   3   1   2   0   1   0   0   0   0   0

   8      * 9.8 21 HRS   52   5   5  19   5  10   5   0   0   0   0   0   0   0   0   0   0   0
   9        17.3         21   4   8   4   0   0   4   8  13  33   4   0   0   0   0   0   0   0
  10        12.6         33   8  13   4   4   8   8   4   4   8   0   0   0   0   0   0   0   0
  11         9.6         58  17   4   0   0   4   4   8   4   0   0   0   0   0   0   0   0   0
  12         6.2        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  13         5.7        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  14        11.2         25  13  17  21   8  13   4   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 10.3         56   7   7   7   2   5   4   3   3   6   1   0   0   0   0   0   0   0

  15        14.0         25   0   8   4  21  17   0   4  17   4   0   0   0   0   0   0   0   0
  16         6.6         83   8   4   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0
  17         4.3        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  18         5.2        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  19         4.6        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  20         8.9         75  13   8   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
  21         7.8         83   0   0   4   0   8   4   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  7.3         81   3   3   1   4   4   1   1   2   1   0   0   0   0   0   0   0   0

  22      *10.3 19 HRS   47  16  21  11   5   0   0   0   0   0   0   0   0   0   0   0   0   0
  23       NO DATA
  24       NO DATA
  25       NO DATA
  26       NO DATA
  27       NO DATA
  28       NO DATA

WKLY  AVG=> 10.3         47  16  21  11   5   0   0   0   0   0   0   0   0   0   0   0   0   0

  29      * 8.3 10 HRS   90   0   0   0   0   0   0   0   0  10   0   0   0   0   0   0   0   0
  30         8.1         92   4   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0
-----------------------------------------------------------------------------------------------
  NOV        9.0         68   6   6   4   3   4   2   1   3   3   1   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  3
STARTING TIME:  0000 HOURS
STARTING DATE:  12/ 1/81

                                                 PERCENTAGE WIND SPEED PROFILE
 DATE      AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-------------------------------------------------------------------------------------------------

   1        12.8           8  17  13  21  21   8   8   4   0   0   0   0   0   0   0   0   0   0
   2        11.4          50   8   4   4  13  13   4   4   0   0   0   0   0   0   0   0   0   0
   3         9.0          75  13   8   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   4         5.4         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   5         9.3          67   8   4   8  13   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  9.2          67   8   5   5   8   3   2   1   0   1   0   0   0   0   0   0   0   0

   6         8.6          75   4   4  13   0   4   0   0   0   0   0   0   0   0   0   0   0   0
   7         7.4          92   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   8         4.0          96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   9       * 6.1 22 HRS   86   0   0   9   5   0   0   0   0   0   0   0   0   0   0   0   0   0
  10        10.3          50   4  17  13   8   8   0   0   0   0   0   0   0   0   0   0   0   0
  11         8.8          67  17   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  12         4.6         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  7.1          81   5   4   6   2   2   0   0   0   0   0   0   0   0   0   0   0   0

  13         3.1         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  14         7.9          79   8   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  15       * 3.0 17 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  16         NO DATA
  17        NO DATA
  18        NO DATA
  19        NO DATA

WKLY  AVG=>  4.7          92   3   2   3   0   0   0   0   0   0   0   0   0   0   0   0   0   0

-------------------------------------------------------------------------------------------------
 DEC         7.4          76   6   4   6   4   2   1   1   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
STARTING TIME:  2300 HOURS
STARTING DATE:   5/18/82

                                                  PERCENTAGE WIND SPEED PROFILE
  DATE   AVG WIND SPD   <10  <11  <12  <13  <14  <16  <18  <20  <22  <24  <26  <28  <30  <32  <34  <36  <38  >38
----------------------------------------------------------------------------------------------------------------
   18    * 9.9  1 HRS   100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   19      6.2           96    4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   20      6.8           88   13    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   21      6.0           92    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   22      7.0           83    0    0    0    0   17    0    0    0    0    0    0    0    0    0    0    0    0

WKLY AVG=> 7.2           90    6    0    0    0    4    0    0    0    0    0    0    0    0    0    0    0    0

   23     14.1           38    0    0    4    4    0   17   25    4    4    4    0    0    0    0    0    0    0
   24      9.5           42   17   21    8   13    0    0    0    0    0    0    0    0    0    0    0    0    0
   25      8.1           58    0   17    4   17    4    0    0    0    0    0    0    0    0    0    0    0    0
   26      7.6           79    8    0    8    0    4    0    0    0    0    0    0    0    0    0    0    0    0
   27      6.0           88    4    0    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   28      7.2           75    0   13    0   13    0    0    0    0    0    0    0    0    0    0    0    0    0
   29      9.4           54    0    0    4    4    0   29    8    0    0    0    0    0    0    0    0    0    0

WKLY AVG=> 8.9           62    4    7    5    7    1    7    5    1    1    1    0    0    0    0    0    0    0

   30     10.1           50    8    4    8   13    8    8    0    0    0    0    0    0    0    0    0    0    0
   31      3.4          100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
----------------------------------------------------------------------------------------------------------------
  MAY      8.0           73    5    4    4    5    3    4    3    0    0    0    0    0    0    0    0    0    0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  5
STARTING TIME:  0000 HOURS
STARTING DATE:   6/ 1/82

                                                         PERCENTAGE WIND SPEED PROFILE
 DATE      AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
    1         4.2        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    2         5.4         88   4   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    3       * 7.0   9 HRS 87  11   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4        NO DATA
    5        NO DATA

WKLY AVG=>  6.0           85   4   1   4   3   2   2   0   0   0   0   0   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  JUN         5.5         93   4   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: CASCADE
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 10/19/81

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10/24 | * 7.2 | 83 | 5 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/31 | 14.4 | 31 | 4 | 5 | 6 | 5 | 10 | 8 | 8 | 7 | 4 | 2 | 5 | 1 | 2 | 1 | 0 | 0 | 0 |
| OCT | 11.1 | 53 | 4 | 4 | 5 | 3 | 6 | 5 | 5 | 4 | 2 | 2 | 3 | 0 | 1 | 0 | 0 | 0 | 0 |
| 11/ 7 | 9.4 | 63 | 9 | 8 | 3 | 3 | 4 | 2 | 1 | 3 | 1 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 11/14 | 10.3 | 56 | 7 | 7 | 7 | 2 | 5 | 4 | 3 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/21 | 7.3 | 81 | 3 | 3 | 1 | 4 | 4 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/22 | *10.3 | 47 | 16 | 21 | 11 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOV | 9.0 | 68 | 6 | 6 | 4 | 3 | 4 | 2 | 1 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/ 5 | 9.2 | 67 | 8 | 5 | 5 | 8 | 3 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/12 | 7.1 | 81 | 5 | 4 | 6 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/15 | * 4.7 | 92 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 7.4 | 76 | 6 | 4 | 6 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/22 | 7.2 | 90 | 6 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/29 | 8.9 | 62 | 4 | 7 | 5 | 7 | 1 | 7 | 5 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 8.0 | 73 | 5 | 4 | 4 | 5 | 3 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/ 3 | * 6.0 | 85 | 4 | 1 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUN | 5.5 | 93 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: CASCADE
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 10/19/81

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 10/24 | * 7.22 | | | 45 |
| 10/31 | 14.37 | | | 258 |
| OCT | 11.1 | 888.1 | 45.3 | 166 |
| 11/ 7 | 9.40 | | | 88 |
| 11/14 | 10.34 | | | 111 |
| 11/21 | 7.34 | | | 44 |
| 11/22 | *10.32 | | | 58 |
| NOV | 9.0 | 888.1 | 40.8 | 78 |
| 12/ 5 | 9.18 | | | 59 |
| 12/12 | 7.10 | | | 30 |
| 12/15 | * 4.65 | | | 13 |
| DEC | 7.4 | 885.8 | 24.6 | 38 |
| 5/22 | 7.18 | | | 22 |
| 5/29 | 8.86 | | | 72 |
| MAY | 8.0 | 888.1 | 48.4 | 51 |
| 6/ 3 | * 6.03 | | | 24 |
| JUN | 5.5 | 888.8 | 60.2 | 12 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

## WEEKLY & MONTHLY WIND DIRECTION PROFILE

Note: The wind direction values read from the strip charts were interpreted as specified by the manufacturer, i.e., .25 inch of strip chart length representing 15 minutes of direction data. No attempt was made to correct wind direction data to account for recorder motor speed variations as ambient temperature varied. The greatest speed variation we noted amounted to + or - 5.06%. Such a correction was made, however, in the wind speed data. Thus the distribution of the wind direction data in the table below does not correspond to the distribution of wind speed over the same period of time.

LOCATION: CASCADE
STARTING TIME: 1700
STARTING DATE: 10/19/81

| WEEK ENDING | -PERCENTAGE PROFILE OF WIND DIRECTION- N | NW | W | SW | S | SE | E | NE |
|---|---|---|---|---|---|---|---|---|
| 10/24 * | 13 | 24 | 36 | 2 | 3 | 3 | 9 | 9 |
| 10/31 | 2 | 13 | 60 | 15 | 8 | 0 | 0 | 0 |
| OCT | 9 | 18 | 49 | 9 | 4 | 2 | 4 | 4 |
| 11/7 | 6 | 29 | 52 | 5 | 1 | 1 | 1 | 6 |
| 11/14 | 7 | 18 | 53 | 15 | 5 | 1 | 1 | 1 |
| 11/21 | 5 | 21 | 46 | 17 | 6 | 2 | 2 | 1 |
| 11/28 * | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| NOV | 6 | 22 | 50 | 12 | 4 | 1 | 1 | 3 |
| 12/5 | 2 | 12 | 64 | 20 | 0 | 0 | 0 | 1 |
| 12/12 | 6 | 17 | 49 | 11 | 7 | 4 | 4 | 2 |
| 12/15 | 8 | 26 | 41 | 1 | 0 | 6 | 7 | 10 |
| sensor malfunctioned during remainder of monitoring period | | | | | | | | |
| DEC | 5 | 16 | 54 | 14 | 3 | 2 | 3 | 3 |
| PERIOD TOT: | 6 | 19 | 51 | 12 | 4 | 2 | 3 | 3 |

* this week contains less than 7 days of direction data;
the direction sensor was aligned with the magnetic north pole

```
     MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM


LOCATION:  CASCADE
DNRC TOWER HEIGHT:  10.0 METERS
NCC TOWER HEIGHT:    6.7 METERS
STARTING TIME:  1600 HOURS
STARTING DATE:  10/19/81
                                             (1.0 = PERFECT SITE/WEATHER STATION CORRELATION)
 WEEK    <-CORRELATION  FACTORS->                FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S
ENDING   MEAN   MINIMUM   MAXIMUM    <.3  <.6  <.9 <1.2 <1.5 <1.8 <2.1 <2.4 <2.7 <3.0 >3.0
-------------------------------------------------------------------------------------------
10/24   *0.84    0.55      1.46        0   17   50   17   17    0    0    0    0    0    0
10/31    0.87    0.61      1.31        0    0   57   29   14    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 OCT     0.86    0.55      1.46        0    8   54   23   15    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
11/ 7    0.71    0.49      1.00        0   29   57   14    0    0    0    0    0    0    0
11/14    0.65    0.45      0.92        0   57   29   14    0    0    0    0    0    0    0
11/21    0.65    0.31      0.91        0   29   57   14    0    0    0    0    0    0    0
11/22   *0.56    0.56      0.56        0  100    0    0    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 NOV     0.65    0.31      1.00        0   46   42   13    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
12/ 5    0.43    0.33      0.53        0  100    0    0    0    0    0    0    0    0    0
12/12    0.53    0.44      0.62        0   71   29    0    0    0    0    0    0    0    0
12/15   *0.64    0.38      1.14        0   67    0   33    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 DEC     0.51    0.33      1.14        0   80   13    7    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 5/22    0.72    0.53      1.13        0   40   40   20    0    0    0    0    0    0    0
 5/29    0.79    0.45      1.23        0   43   29   14   14    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 MAY     0.74    0.40      1.23        0   43   36   14    7    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 6/ 3   *0.59    0.40      0.84        0   60   40    0    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
 JUN     0.56    0.49      0.61        0   67   33    0    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------
STUDY
PERIOD   0.67    0.31      1.46        0   46   36   13    4    0    0    0    0    0    0

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.
```

## MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
## MEAN WIND YEAR

SITE LOCATION: CASCADE NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

| MONTH | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (F) | AVG WIND POWER DENSITY (W/M2) |
|---|---|---|---|---|
| JAN | 12.1 | 887.7 | 24.9 | 155 |
| FEB | 9.6 | 887.3 | 29.6 | 72 |
| MAR | 10.3 | 884.5 | 39.5 | 81 |
| APR | 9.8 | 886.9 | 40.2 | 89 |
| MAY | 9.1 | 886.3 | 59.4 | 65 |
| JUN | 9.6 | 887.5 | 63.6 | 77 |
| JUL | 7.7 | 889.5 | 71.4 | 42 |
| AUG | 7.8 | 889.0 | 71.2 | 43 |
| SEP | 8.3 | 890.0 | 58.2 | 49 |
| OCT | 10.3 | 889.5 | 49.2 | 98 |
| NOV | 9.6 | 888.7 | 25.2 | 94 |
| DEC | 10.8 | 887.2 | 28.9 | 132 |
| YEARLY AVERAGE:<br>1973 | 9.6 | | | 82 |

```
         MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MINIMUM WIND YEAR


SITE LOCATION: CASCADE            NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                 (F)                  (W/M2)
-----------------------------------------------------------------------------------------
 JAN        8.8             887.7                 6.5                   88

 FEB        9.6             887.1                18.8                  100

 MAR        9.2             884.5                34.7                   81

 APR        8.8             886.8                40.7                   59

 MAY        7.2             886.4                51.5                   39

 JUN        7.6             887.4                62.9                   44

 JUL        6.3             889.5                69.0                   24

 AUG        6.7             889.2                68.5                   27

 SEP        6.9             890.2                62.9                   29

 OCT        7.2             889.3                49.4                   38

 NOV        8.1             888.6                33.4                   43

 DEC       11.8             886.6                34.6                  154

-----------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979       8.2                                                        59
```

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                  MAXIMUM WIND YEAR


SITE LOCATION: CASCADE            NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE       AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)               (F)                   (W/M2)
-------------------------------------------------------------------------------------
 JAN       13.1               883.8               19.8                   237

 FEB       13.4               885.2               33.8                   168

 MAR       11.5               882.2               33.3                   162

 APR        8.9               886.2               47.1                    59

 MAY        9.4               885.5               49.5                    76

 JUN        8.7               886.2               66.9                    53

 JUL        7.8               888.9               72.9                    44

 AUG        6.9               890.6               62.9                    23

 SEP        7.2               892.3               54.8                    39

 OCT        8.9               891.6               51.4                    68

 NOV       10.3               888.3               38.7                    97

 DEC       13.2               885.5               32.5                   190

-------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974       9.9                                                          100
```

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                  MEAN WIND YEAR

SITE LOCATION: CASCADE             NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                    PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
---------------------------------------------------------------------------------------------

 JAN    12.1     36  10   4   4   5  16   5   8   7   3   1   1   0   0   0   0   0   0   0

 FEB     9.6     53  15   5   6   5   9   4   2   1   0   0   0   0   0   0   0   0   0   0

 MAR    10.3     48  13   7   6   5  10   4   3   2   0   0   0   0   0   0   0   0   0   0

 APR     9.8     56  12   5   5   5   6   3   1   5   0   2   0   0   0   0   0   0   0   0

 MAY     9.1     59  14   4   5   2   6   3   2   3   0   0   0   0   0   0   0   0   0   0

 JUN     9.6     57  13   5   2   2  10   2   3   4   1   0   0   0   0   0   0   0   0   0

 JUL     7.7     77   7   4   2   3   3   1   1   1   1   0   0   0   0   0   0   0   0   0

 AUG     7.8     75  10   4   2   2   5   1   1   2   0   0   0   0   0   0   0   0   0   0

 SEP     8.3     69  10   5   2   4   5   2   2   2   0   0   0   0   0   0   0   0   0   0

 OCT    10.3     48  13   9   3   4   8   4   6   4   1   0   0   0   0   0   0   0   0   0

 NOV     9.6     56  11   4   4   3   7   7   3   4   0   1   0   0   0   0   0   0   0   0

 DEC    10.8     45   9   5   4   3  12   7   3   8   1   1   1   0   0   0   0   0   0   0

---------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973    9.6     57  11   5   4   4   8   4   3   4   1   0   0   0   0   0   0   0   0   0
```

## MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
## MINIMUM WIND YEAR

SITE LOCATION: CASCADE NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

| | AVG | PERCENT OF WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | SPEED | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | <40 | >40 |
| JAN | 8.8 | 52 | 11 | 3 | 6 | 3 | 9 | 7 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 9.6 | 54 | 7 | 5 | 3 | 3 | 11 | 6 | 2 | 5 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 9.2 | 54 | 12 | 5 | 5 | 4 | 10 | 5 | 4 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| APR | 8.8 | 64 | 9 | 6 | 2 | 6 | 6 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 7.2 | 82 | 6 | 1 | 2 | 2 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUN | 7.6 | 74 | 8 | 3 | 3 | 2 | 8 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUL | 6.3 | 87 | 5 | 3 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 6.7 | 85 | 5 | 2 | 1 | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 6.9 | 82 | 7 | 2 | 3 | 1 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 7.2 | 76 | 6 | 2 | 4 | 3 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NOV | 8.1 | 67 | 14 | 4 | 5 | 2 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 11.9 | 41 | 9 | 5 | 4 | 4 | 12 | 7 | 5 | 7 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| YEARLY AVERAGE: 1979 | 8.2 | 68 | 8 | 3 | 3 | 3 | 6 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                 MAXIMUM WIND YEAR


SITE LOCATION: CASCADE            NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.67
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                        PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN    13.1     34   8   7   5   4  12   5   6   8   3   4   3   1   0   0   1   0   0   0

 FEB    13.4     23  11   7   7   4  22   9   7   7   2   2   0   0   0   0   0   0   0   0

 MAR    11.5     41  12   6   5   5   9   6   2   7   2   1   1   2   0   0   0   0   0   0

 APR     8.9     63  13   3   4   5   5   4   1   2   0   0   0   0   0   0   0   0   0   0

 MAY     9.4     54  14   5   6   5   5   4   2   4   0   0   0   0   0   0   0   0   0   0

 JUN     8.7     67  10   3   7   1   5   4   1   2   0   0   0   0   0   0   0   0   0   0

 JUL     7.8     72  10   5   3   1   3   2   2   2   0   0   0   0   0   0   0   0   0   0

 AUG     6.9     81  12   4   0   1   2   0   0   0   0   0   0   0   0   0   0   0   0   0

 SEP     7.2     78   8   3   1   2   5   2   1   0   0   0   0   0   0   0   0   0   0   0

 OCT     8.9     59  14   5   4   4   5   2   5   2   0   0   0   0   0   0   0   0   0   0

 NOV    10.3     47  10   8   5   5  11   5   5   4   0   0   0   0   0   0   0   0   0   0

 DEC    13.2     31   8   7   8   3  11   8   6   9   3   4   1   0   0   0   0   0   0   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974    9.9     54  11   5   5   3   8   4   3   4   1   1   0   0   1   1   0   0   0   0
```

# APPENDIX I

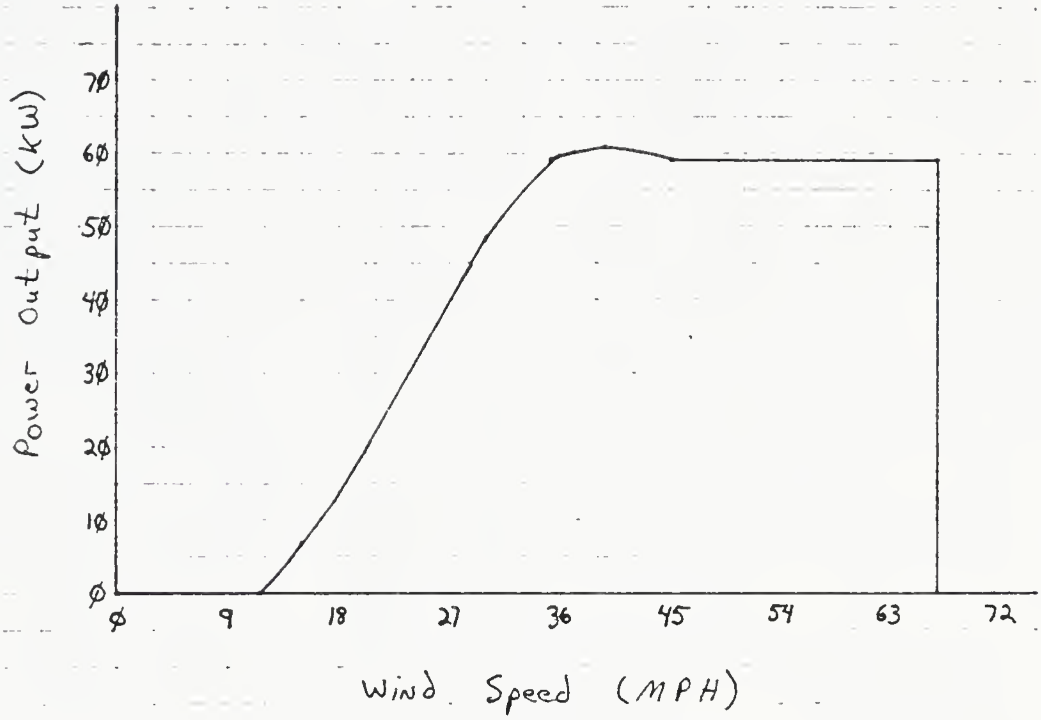
## Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon, Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

# APPENDIX II

Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
Wind Speed Versus Generator kWh Output



## APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

### I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

### II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   b) the total amount of your proposed investment.
      i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
      ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
      iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   c) Complete warranty information.
   d) Complete information for utility/home electric interface connection.
   e) Maintenance schedules and their costs.
   f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

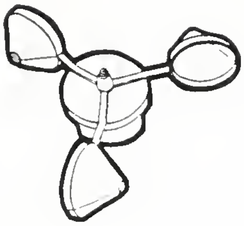
If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

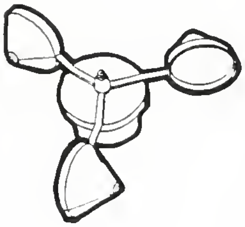
Then, here, in general, are the steps to getting those first kilowatts flowing:

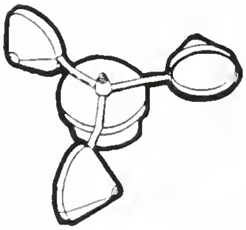
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements. .
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

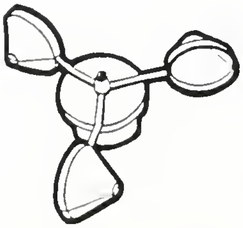
4) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.
5) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The McGillivray Place, Chinook, MT

December 17, 1980 - April 3, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #SSR-1 at the Jerry McGillivray place near Chinook, Montana from December 17, 1980 to April 3, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensor used in the system which gathered this data. The system included a single-channel strip chart recorder housed in a plastic case, a 4-pole cup anemometer, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensor to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operating specifications for the anemometer are:
Wind velocity range: 3- 150 MPH
Temperature range -60 to 200 degrees F.

The operating specifications for the strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The the single-channel strip chart recorder records a wind speed reading every two seconds by making a mark on the strip chart. To make the mark, an impact bar strikes the top side of the meter needle, which then touches pressure-sensitive paper (a "strip chart") moving slowly beneath the needle. These dots accumulate on the moving paper forming a graph of the wind speed.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On December 17, 1980, under contract with DNRC, Gunderson Consulting installed DNRC's wind monitoring system #SSR-1 at the Jerry McGillivray farm southeast of Chinook, Montana (mailing address: Route 1, Box 78, Chinook, 59523). Between the date of installation and April 3, 1981, Jerry charged the batteries and changed the rolls of strip chart paper as they were filled. The monitoring system worked according to specifications during the entire monitoring period; the only malfunction was in the battery charger, which was replaced. Jerry forwarded the filled strip charts to DNRC and in June 1982, DNRC contracted with Gunderson Consulting to analyze and summarize the data on the strip charts.

To locate the monitoring site, drive south from Chinook on State 240 to a gravel road two miles past the city landfill. Turn east onto the gravel and drive three-quarters of a mile to a fork. Take the north fork and continue east one-quarter of a mile to a mail box. Turn north at the mail box and drive one-quarter of a mile to the McGillivray farm house.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged then into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Havre) is at 6.1 meters while the anemometer at the site was 6.7 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 6.7 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

We found the correlation factors between the Chinook data and the Havre weather station data to be invalid. For one thing, the study period frequency percentage spectrum is not the normal distribution which characterizes a valid correlation; for another, the mean and maximum correlation factors are much larger than would be expected.

We conjecture that this lack of correlation between Chinook and Havre is because the two towns lie in different wind patterns, even though only 28 miles separate them. Havre lies just beyond the northwestern corner of the Bear Paw mountains while Chinook lies near the northeastern corner. Perhaps these mountains divide the weather as it approaches from the north and northwest. During the study period, this difference had a seasonal pattern--the wind speeds in Havre moderated as winter turned to spring, while they remained fairly stable in Chinook; by the same token, the resulting correlations become more and more fantastic from the beginning of the study to the end (December to April).

Because a valid correlation does not exist between Chinook and its nearest weather service station, this report doesn't contain projections of yearly average wind speed and power density for Chinook.

This is the first instance where we have found an invalid correlation between a monitoring site and its nearest weather station. It is especially interesting because the two locations are less that 30 miles apart.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage [illegible]

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this example, the wind blew between 0 and 10 MPH 82% of the time; it blew between 10 and 11 MPH 6% of the time, etc.4% between 12 and 13 MPH, etc.

***********

Next is the "Weekly and Monthly Average Wind Power Density" sheet. This sheet contains the weekly and monthly average wind speed in MPH and wind power density in Watts per square meter for the monitoring period. The average monthly average air pressure and temperature are also listed.

***********

Next is the "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary. It gives the correlation factors which compare the wind speeds at the monitoring site (Chinook) to those at the nearest NCC weather station (Havre). The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors", which shows the percent of correlation factors that fall into each bracket of the spectrum. Correlation factors express the wind speed at the monitoring site as a percent of the wind speed at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

The smoother the distribution of these factors across the spectrum, the more valid they are considered to be. As the reader can see, the distribution of correlation factors is erratic which means that the correlation factors are invalid and that wind speeds at Chinook cannot be compared to wind speeds in Havre over time even though the two places are less than 30 miles apart. As a result, we were unable to make long-term projections about wind patterns in Chinook.

Local residents are probably aware of their unusual weather pattern and probably have an understanding of the causes. It is possible that the Chinook data would correlate with data from some other weather service station, perhaps the one in Glasgow, 140 miles to the east, or a Canadian station to the north.

***********

And finally are the five pages titled, "Wind Speed Summary (In MPH) and Percentage Spectrum." These pages summarize the wind speed in MPH during the monitoring period on a daily, weekly and monthly basis during the monitoring period. These sheets have the same format as the weekly-monthly summary described above.

WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: CHINOOK
STARTING TIME: 1400 HOURS
STARTING DATE: 12/17/80

TOWER HEIGHT: 10 METERS

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12/20 | *12.9 | 28 | 6 | 6 | 6 | 4 | 9 | 15 | 7 | 7 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 12.9 | 28 | 6 | 6 | 6 | 4 | 9 | 15 | 7 | 7 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/17 | 6.5 | 90 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/24 | 5.9 | 88 | 0 | 1 | 3 | 0 | 1 | 1 | 2 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/31 | 11.9 | 39 | 5 | 5 | 5 | 8 | 9 | 11 | 8 | 7 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JAN | 8.7 | 64 | 2 | 3 | 4 | 4 | 5 | 6 | 5 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/ 7 | 11.9 | 43 | 7 | 5 | 7 | 4 | 10 | 5 | 4 | 5 | 4 | 1 | 4 | 1 | 1 | 0 | 0 | 0 | 0 |
| 2/14 | 14.6 | 36 | 4 | 4 | 4 | 6 | 9 | 7 | 3 | 7 | 7 | 7 | 4 | 3 | 1 | 0 | 1 | 0 | 0 |
| 2/21 | 27.5 | 3 | 1 | 1 | 2 | 4 | 2 | 2 | 5 | 4 | 8 | 9 | 10 | 12 | 7 | 7 | 4 | 7 | 13 |
| 2/28 | 9.4 | 67 | 4 | 3 | 1 | 3 | 6 | 3 | 4 | 6 | 1 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 15.9 | 37 | 4 | 3 | 3 | 4 | 7 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 2 | 2 | 1 | 2 | 3 |
| 3/ 1 | * 5.8 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/ 7 | 6.9 | 52 | 8 | 8 | 8 | 4 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/14 | 8.4 | 61 | 9 | 8 | 10 | 4 | 4 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/21 | 9.1 | 62 | 6 | 4 | 4 | 4 | 5 | 7 | 7 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/28 | 13.0 | 47 | 4 | 4 | 2 | 2 | 4 | 12 | 5 | 2 | 2 | 7 | 7 | 4 | 0 | 0 | 0 | 0 | 0 |
| MAR | 10.4 | 53 | 6 | 5 | 6 | 4 | 5 | 7 | 4 | 1 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4/ 3 | *15.9 | 24 | 3 | 2 | 7 | 8 | 9 | 11 | 8 | 5 | 10 | 3 | 6 | 1 | 1 | 2 | 0 | 1 | 0 |
| APR | 15.8 | 28 | 0 | 0 | 5 | 5 | 12 | 10 | 10 | 7 | 10 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: CHINOOK
TOWER HEIGHT: 10 METERS
STARTING TIME: 1400 HOURS
STARTING DATE: 12/17/80

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 12/20 | *12.9 | | | 222 |
| DEC | 12.9 | 927.5 | 18.9 | 222 |
| 1/17 | 6.5 | | | 20 |
| 1/24 | 5.9 | | | 44 |
| 1/31 | 11.9 | | | 165 |
| JAN | 8.7 | 927.1 | 28.5 | 103 |
| 2/ 7 | 11.9 | | | 183 |
| 2/14 | 14.6 | | | 309 |
| 2/21 | 27.5 | | | 1450 |
| 2/28 | 9.4 | | | 115 |
| FEB | 15.9 | 924.1 | 27.3 | 522 |
| 3/ 1 | * 5.8 | | | 14 |
| 3/ 7 | 6.9 | | | 66 |
| 3/14 | 8.4 | | | 56 |
| 3/21 | 9.1 | | | 82 |
| 3/28 | 13.0 | | | 256 |
| MAR | 10.4 | 922.7 | 38.1 | 154 |
| 4/ 3 | *15.9 | | | 344 |
| APR | 15.8 | 920.4 | 46.4 | 304 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: CHINOOK
DNRC TOWER HEIGHT: 6.7 METERS
NCC TOWER HEIGHT: 6.1 METERS
STARTING TIME: 1300 HOURS
STARTING DATE: 12/17/80

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION FACTORS-> | | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 12/20 | *1.34 | 1.00 | 1.40 | 0 | 0 | 0 | 25 | 75 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 1.34 | 1.00 | 1.40 | 0 | 0 | 0 | 25 | 75 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/17 | 1.93 | 1.00 | 1.93 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| 1/24 | 1.21 | 0.75 | 2.18 | 0 | 0 | 43 | 29 | 0 | 14 | 0 | 14 | 0 | 0 | 0 |
| 1/31 | 2.31 | 0.88 | 4.77 | 0 | 0 | 14 | 0 | 14 | 14 | 14 | 0 | 14 | 14 | 14 |
| JAN | 1.77 | 0.75 | 4.77 | 0 | 0 | 27 | 13 | 7 | 13 | 13 | 7 | 7 | 7 | 7 |
| 2/ 7 | 2.37 | 1.00 | 4.30 | 0 | 0 | 0 | 0 | 14 | 14 | 29 | 0 | 14 | 14 | 14 |
| 2/14 | 3.45 | 1.00 | 6.29 | 0 | 0 | 0 | 0 | 0 | 14 | 14 | 14 | 0 | 0 | 57 |
| 2/21 | 2.04 | 1.00 | 2.53 | 0 | 0 | 0 | 0 | 0 | 14 | 57 | 14 | 14 | 0 | 0 |
| 2/28 | 1.75 | 0.98 | 4.31 | 0 | 0 | 0 | 29 | 43 | 14 | 0 | 0 | 0 | 0 | 14 |
| FEB | 2.40 | 0.98 | 6.29 | 0 | 0 | 0 | 7 | 14 | 14 | 25 | 7 | 7 | 4 | 21 |
| 3/ 1 | *1.71 | 1.00 | 1.71 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 |
| 3/ 7 | 3.36 | 1.00 | 3.36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 3/14 | 2.61 | 1.00 | 3.97 | 0 | 0 | 0 | 0 | 29 | 14 | 0 | 0 | 0 | 14 | 43 |
| 3/21 | 2.29 | 0.61 | 6.32 | 0 | 0 | 29 | 0 | 0 | 14 | 14 | 29 | 0 | 0 | 14 |
| 3/28 | 2.52 | 0.84 | 3.82 | 0 | 0 | 14 | 0 | 14 | 0 | 14 | 0 | 14 | 0 | 43 |
| MAR | 2.36 | 0.61 | 6.32 | 0 | 0 | 12 | 4 | 12 | 19 | 8 | 8 | 4 | 4 | 31 |
| 4/ 3 | *1.66 | 1.00 | 2.53 | 0 | 0 | 0 | 17 | 17 | 50 | 0 | 0 | 17 | 0 | 0 |
| APR | 1.87 | 1.00 | 2.53 | 0 | 0 | 0 | 0 | 33 | 33 | 0 | 0 | 33 | 0 | 0 |
| STUDY PERIOD | 2.19 | 0.61 | 6.32 | 0 | 0 | 9 | 8 | 16 | 16 | 14 | 7 | 7 | 4 | 20 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

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PAGE 1

             WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM

LOCATION:  CHINOOK                 TOWER HEIGHT:  10 METERS
STARTING TIME:  1400 HOURS
STARTING DATE:  12/17/80

                                          PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
------------------------------------------------------------------------------------------------
  17     *10.5 10 HRS   40  10  20  20  10   0   0   0   0   0   0   0   0   0   0   0   0   0
  18      13.3          29   4   4   4   0  13  25   8   4   4   4   0   0   0   0   0   0   0
  19      16.1          21   4   0   4   0   4  13  13  17  21   4   0   0   0   0   0   0   0
  20     *11.7 10 HRS   30  10  10   0  20  20  10   0   0   0   0   0   0   0   0   0   0   0
  21      NO DATA

WKLY  AVG=> 12.9        28   6   6   6   4   9  15   7   7   9   3   0   0   0   0   0   0   0

------------------------------------------------------------------------------------------------
 DEC      12.9          28   6   6   6   4   9  15   7   7   9   3   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
      THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  1400 HOURS
STARTING DATE:    1/17/81

                                              PERCENTAGE WIND SPEED PROFILE
  DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
   17      * 6.5 10 HRS   90   0  10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  6.5          90   0  10   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

   18         8.3         75   0   0   0   0   8   4   4   8   0   0   0   0   0   0   0   0   0
   19         4.1        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   20         5.6         83   0   4  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   21         3.9        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   22      * 5.2 16 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   23         4.4        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   24         9.7         63   0   0   4   0   0   4   8  17   4   0   0   0   0   0   0   0   0

WKLY  AVG=>  5.9          88   0   1   3   0   1   1   2   4   1   0   0   0   0   0   0   0   0

   25        18.8          0   0   0   0   0   4  38  25  25   8   0   0   0   0   0   0   0   0
   26        10.2         50   0   4   8   4  21   8   4   0   0   0   0   0   0   0   0   0   0
   27         6.6         75   4  13   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   28         7.7         58   0   4   4  17   8   4   0   0   0   4   0   0   0   0   0   0   0
   29        19.5          0   0   0   0   0  13  25  21  21  13   8   0   0   0   0   0   0   0
   30         8.5         71   0   4   4  13   8   0   0   0   0   0   0   0   0   0   0   0   0
   31        11.9         17  29   8   8  25   8   0   4   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 11.9          39   5   5   5   8   9  11   8   7   3   2   0   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  JAN         8.7         64   2   3   4   4   5   6   5   5   2   1   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  3
STARTING TIME:  0000 HOURS
STARTING DATE:   2/ 1/81

                                               PERCENTAGE WIND SPEED PROFILE
 DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
   1        11.1        33   8   8  17   4  17  13   0   0   0   0   0   0   0   0   0   0   0
   2         7.5        75   8   4   0   4   8   0   0   0   0   0   0   0   0   0   0   0   0
   3         8.9        54  25   4   8   4   0   4   0   0   0   0   0   0   0   0   0   0   0
   4         9.0        54   4   4   8   8  13   4   0   4   0   0   0   0   0   0   0   0   0
   5        11.6        42   4   4   8   0  17   4  21   0   0   0   0   0   0   0   0   0   0
   6        16.5        29   0  13   4   4   0   4   0   8  17   4  13   4   0   0   0   0   0
   7        18.7        13   0   0   4   4  13   8   8  25   8   0  13   0   4   0   0   0   0

WKLY AVG=> 11.9         43   7   5   7   4  10   5   4   5   4   1   4   1   1   0   0   0   0

   8        21.7        13   0   0   0   0   8   4   8   8   4  25  13  13   4   0   0   0   0
   9        13.5        42  17   0   4   4   4   0   4   8   4   4   8   0   0   0   0   0   0
  10        17.4        17   0   0   4   8  21  17   0  13   4   4   4   4   4   0   0   0   0
  11        13.5        38   4  13   4   8   0   4   0   4  21   4   0   0   0   0   0   0   0
  12        12.4        54   0   4   4   4   0   8   0   8  13   4   0   0   0   0   0   0   0
  13         9.5        54   4   0   0   0  21   8   8   4   0   0   0   0   0   0   0   0   0
  14        14.0        33   4   8   8  17   8   4   0   0   0   8   0   4   0   0   4   0   0

WKLY AVG=> 14.6         36   4   4   4   6   9   7   3   7   7   7   4   3   1   0   1   0   0

  15        32.3         0   0   0   0   0   0   0   0   0   0   0   8  25  17  25   4  17   4
  16        32.7         0   0   0   0   0   0   0   4   4   4   4  13   8  17   4   0   8  33
  17        33.4         0   0   0   0   0   0   0   0   4   0   8  13   4  13   8   8  17  25
  18        29.0         4   4   0   0   0   0   0   8   4  21   8   4   8   4   0   4   0  29
  19        15.5        17   4   0   4  17   8  17   8   8   8   4   4   0   0   0   0   0   0
  20        25.7         0   0   0   8   4   0   0   4   8  17  13   8  13   0   8  13   4   0
  21        24.3         0   0   4   0   4   8   0   8   0   4  25  17  25   0   4   0   0   0

WKLY AVG=> 27.5          3   1   1   2   4   2   2   5   4   8   9  10  12   7   7   4   7  13

  22        14.8        33   4   8   0   0   8   4  17  13   4   4   4   0   0   0   0   0   0
  23         8.8        75   0   0   0   4   8   4   0   0   0   8   0   0   0   0   0   0   0
  24        16.1         8  13   4   4  13   8   8   8  25   4   4   0   0   0   0   0   0   0
  25       *10.6 12 HRS  50  17   0   8   0  25   0   0   0   0   0   0   0   0   0   0   0   0
  26         7.2        92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  27         4.0       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  28         4.6       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.4         67   4   3   1   3   6   3   4   6   1   3   1   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  FEB       15.9        37   4   3   3   4   7   4   4   5   5   5   4   4   2   2   1   2   3

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
STARTING TIME:  0000 HOURS
STARTING DATE:   3/ 1/81

                                                  PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD   <10  <11  <12  <13  <14  <16  <18  <20  <22  <24  <26  <28  <30  <32  <34  <36  <38  >38
-----------------------------------------------------------------------------------------------------------------
    1     * 5.8 16 HRS   100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2      NO DATA
    3      NO DATA
    4      NO DATA
    5      NO DATA
    6     * 4.0  1 HRS   100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    7           9.8       50    8    8    8    4   21    0    0    0    0    0    0    0    0    0    0    0    0

WKLY AVG=>  6.5           71    5    5    5    2   12    0    0    0    0    0    0    0    0    0    0    0    0

    8           8.8       54    8   21   17    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    9           7.7       63   13    4   21    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   10           7.8       54   17   13   17    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   11           9.5       63    0    4    4    0   17   13    0    0    0    0    0    0    0    0    0    0    0
   12           5.2      100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   13           5.9       88    8    4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   14          13.9        4   17    8    8   25    8   17   13    0    0    0    0    0    0    0    0    0    0

WKLY AVG=>  8.4           61    9    8   10    4    4    4    2    0    0    0    0    0    0    0    0    0    0

   15          10.4       50   17    4    4    0    8    0   13    0    4    0    0    0    0    0    0    0    0
   16           8.3       67    0    4    0    0    0   21    8    0    0    0    0    0    0    0    0    0    0
   17           5.9       83    4    4    0    4    4    0    0    0    0    0    0    0    0    0    0    0    0
   18          12.3       25   13    0   21   17    8    4   13    0    0    0    0    0    0    0    0    0    0
   19          11.6       50    0    8    4    8    8    8    8    4    0    0    0    0    0    0    0    0    0
   20           5.9      100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   21           9.7       58    8    4    0    0    8   13    4    0    4    0    0    0    0    0    0    0    0

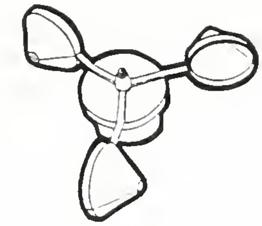
WKLY AVG=>  9.1           62    6    4    4    4    5    7    7    1    1    0    0    0    0    0    0    0    0

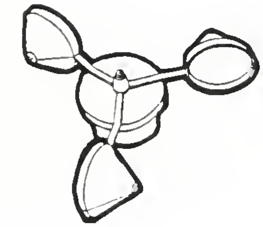
   22          14.1       21    4    4    4    4   17   33   13    0    0    0    0    0    0    0    0    0    0
   23           9.7       67    0    0    0    4    0   17    4    4    0    4    0    0    0    0    0    0    0
   24          13.1       54    0    4    0    0    0    8    4    0    0   13    8    8    0    0    0    0    0
   25          16.2       38    0    8    0    0    4    4    4    0    4    8   21    8    0    0    0    0    0
   26          21.1       13    4    0    0    0    0    4    8    8   13   25   17    8    0    0    0    0    0
   27           8.4       79    8    4    8    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   28           8.3       58    8    4    4    4    4   17    0    0    0    0    0    0    0    0    0    0    0

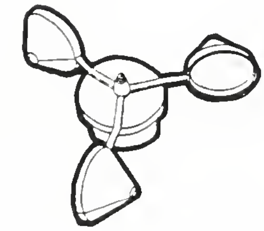
WKLY AVG=> 13.0           47    4    4    2    2    4   12    5    2    2    7    7    4    0    0    0    0    0

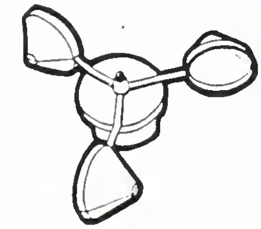
   29          15.3       33    0    8    0    8    0   13    4    4   17    0    8    4    0    0    0    0    0
   30          17.8        0   13    4   21   13   17    4    4    4    0    0    4    0    4    8    0    4    0
   31          14.9       29    4    0    4    8    4   17    8    4   13    0    4    0    0    4    0    0    0
-----------------------------------------------------------------------------------------------------------------
   MAR         10.4       53    6    5    6    4    5    7    4    1    2    2    2    1    0    0    0    0    0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```









# Survey of Wind Power
# at
## The Jim Salmond Place, Choteau, MT
September 9, 1980 - December 8, 1980

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC a wind monitoring system #DSR-2 at the Jim Salmond place near Choteau, Montana from September 9, 1980 to December 8, 1980.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensors used in the system which gathered this data. The system includes: a model A11-132 dual strip chart recorder housed inside a model A75-003 plastic case; a model A75-104 4-pole cup anemometer; a model A75-301 wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensors to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes .

The operational specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operational specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH
Temperature range -60 to 200 degrees F.

The operational specifications for the model A11-132 strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The strip chart recorder records a wind speed and direction reading every two seconds by making a mark on the pressure sensitive strip chart paper as it crosses a metal plate. To make the mark, an impact bar strikes the top side of the meter needles, one for wind speed and one for wind direction, which then touch the sensitive paper.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On September 9, 1980, under contract with DNRC, Gunderson Consulting installed wind monitoring system #DGR-2 at the Jim Salmond farm west of Choteau, Montana. (Mailing address: Box 606, Choteau, Montana.) Between the date of installation and December 8, 1980, Jim charged the batteries and changed the rolls of strip chart paper as they were filled. He mailed the filled strip charts to Gunderson Consulting who reviewed them for signs of equipment malfunction, then delivered them to the Renewable Energy Bureau of DNRC. In June 1982 the Department contracted with Gunderson Consulting to analyze and summarize the data.

To locate the monitoring site, turn west off U.S. Highway 287 on a road one mile south of Choteau. Follow this road 18 to 20 miles to a fork. Follow the south fork toward Deep Creek and the Belview School two to three miles, then one-half mile west.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computed calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

The weekly and monthly wind direction summaries were prepared manually from the marks made by the wind direction needle on the eight direction tracks on strip chart. (One track on the strip chart is assigned to each octant of the compass--N, NE, E, SE, etc.). For each summary period, the operator counted the number of quarter-inch (15-minute) marks in each direction track on the strip chart at the same time he digitized the wind speed curve. He then divided the total number of marks in each direction track by the total number of marks in all direction tracks during the same period to derive the percentage of time the wind blew in each octant for the summary period.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Great Falls) is at 6.7 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station at Gore Hill in Great Falls. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three- hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most

useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P = (1/2)pkV^3$$

where P = wind power density
p = air density
V = wind speed
k = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density p is defined as: p = A/(RT)

where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed gives all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## Data Use

First, refer to Appendix I and compare the average wind power density at your monitored site to the densities at other sites in the state. (Comparison of wind power densities provides the best picture of how one site's potential compares with others.)

Next, estimate the power output you might expect from a particular wind generator installed at your site. You will need the generator manufacturer's wind-speed-versus-power output graph, or "power characteristic curve' as it is sometimes called (Appendix II is such a curve for a Holec Windmatic model 14S wind generator), and the "Average Monthly and Yearly Wind Speed and Percentage Speed Profile" of your site. Follow the procedure in the example below to estimate yearly (or monthly) generator ouput. Then, to calculate a dollar value of the power that generator might generate under the conditions at your site, multiply the estimated generator output by the value of the electricity you would be displacing.

In the following example use the Power Characteristic Curve in Appendix II and the following annual wind speed percentage spectrum:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these annual percentage figures into the number of hours per year the wind blew in each bracket. Multiply the percent value from the percentage spectrum by the number of hours in a year, (365 X 24 = 8,760 hours in a year). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds in the less-than-10-MPH bracket. For the second bracket, the wind blew .05 X 8,760 = 438 hours at speeds between 10 and 10.99 MPH. This process can be continued for each bracket of the spectrum. The final result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

The next step is to assign a MPH value to the middle of each velocity bracket and then use the Power Characteristic Curve to find the generator's power output for each associated midpoint speed. The midpoint of each velocity bracket has been rounded to the nearest MPH for convenience below.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KW) FROM POWER CHARACTERISTIC CURVE

To do the final step, multiply the number of hours in each bracket by the generator output and add all of the ouputs together to obtain the total generator output for the period, which, in this example, is one year.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

In this example, the generator output for the total period (one year) is 51,771 KWh. To find the value of the electricity which would theoretically be displaced by this generator at a site with this wind speed profile, multiply the value of the electricity by the total production. In this example we will use $.0625/KWh for the unit value of displaced electricity; therefore, the total value of the displaced electricity would be $3,235.69 per year.

However, many factors other than the cost of the generator and the value of displaced electricity must be considered to make a realistic evaluation of the economics of wind electric generation at your site--factors such as: the one-time costs of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for the foundation, freight charges, fees for inspection and system checkout, and the continuous expenses of insurance, operation and maintenance. The following breakdown gives a broad guideline for the cost of a larges scale wind development:

| | |
|---|---|
| Generator and Blade Assembly - | 57% |
| Tower and Site Access - | 11% |
| Foundation/Site Preparation - | 9% |
| Operations/Maintenance - | 9% |
| Assembly/Checkout - | 8% |
| Other - | 4% |
| Equipment Transportation - | 2% |

Source: from publication SERI/SP-732-728 pulblished by the Solar Energy Research Institute, October 1980.

Not all of these costs will apply in the same percentages to every installation, but the likelihood is always a good that other costs will occur in their place.

As a rule of thumb, a wind site that has a wind power density of over 200 watts per square meter and has a minimum average wind speed of 12 MPH for at least six months per year should considered for wind development. The final decision to develop your wind potential is an investment decision which deserves the same degree of careful analysis as you give any other development investment. Appendix III is a suggested wind electric generation development guide.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

The multi-page summary titled "Wind Speed Summary (in MPH) and Percentage Spectrum" contains daily, weekly and monthly average wind speeds and a wind speed percentage spectrum for each speed average. This summary should be interpreted in the same manner as the preceeding summary.

On the summary sheet titled, "Weekly and Monthly Average Wind Power Density," the last column gives the weekly and monthly average wind power density at the site during the monitoring period. The average wind speed in mph is also shown.

The summary sheet titled, "Weekly & Monthly Wind Direction Profile," gives the approximate percent of time the wind was blowing in each of the 8 different compass directions during the monitoring period. (Please note that these directions are based on magnetic North, not geographic North.)

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors" for each time period, which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these

sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But while the preceeding summaries estimate wind power density, these estimate wind speed averages--the mean, minimum and maximum monthly and yearly average wind speeds likely to occur at the site--and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: CHOTEAU  TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 9/ 9/80

| WEEK | WKLY AVG SPD | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MPH / DAY | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
| 9/13 | * 7.5 | 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/20 | 13.0 | 43 | 7 | 11 | 8 | 7 | 7 | 2 | 1 | 1 | 1 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| 9/27 | 10.0 | 61 | 4 | 8 | 5 | 2 | 4 | 7 | 5 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 11.1 | 54 | 5 | 8 | 6 | 4 | 5 | 5 | 4 | 3 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 10/ 4 | 12.8 | 46 | 6 | 7 | 4 | 6 | 5 | 5 | 4 | 8 | 2 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 0 |
| 10/11 | 10.3 | 59 | 8 | 5 | 5 | 3 | 4 | 6 | 2 | 2 | 3 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| 10/18 | 12.0 | 38 | 3 | 7 | 9 | 3 | 14 | 15 | 6 | 3 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10/25 | 9.2 | 65 | 7 | 4 | 4 | 4 | 5 | 3 | 1 | 3 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 |
| OCT | 10.2 | 59 | 6 | 5 | 5 | 3 | 7 | 6 | 2 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 11/ 1 | 9.3 | 71 | 4 | 3 | 2 | 3 | 6 | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 11/ 8 | 19.0 | 22 | 2 | 7 | 4 | 2 | 12 | 7 | 6 | 4 | 5 | 4 | 3 | 2 | 1 | 4 | 5 | 4 | 7 |
| 11/10 | *14.4 | 38 | 2 | 4 | 4 | 11 | 13 | 0 | 4 | 7 | 4 | 2 | 0 | 4 | 0 | 4 | 0 | 0 | 0 |
| 11/22 | 16.9 | 33 | 5 | 6 | 3 | 1 | 9 | 3 | 8 | 8 | 1 | 3 | 3 | 2 | 3 | 1 | 4 | 1 | 7 |
| 11/29 | 14.2 | 44 | 5 | 7 | 2 | 5 | 5 | 4 | 4 | 3 | 3 | 5 | 2 | 2 | 2 | 0 | 1 | 2 | 3 |
| NOV | 16.2 | 34 | 4 | 6 | 3 | 4 | 9 | 5 | 6 | 5 | 3 | 4 | 2 | 2 | 2 | 2 | 3 | 2 | 5 |
| 12/ 6 | 6.1 | 88 | 4 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/13 | 16.2 | 36 | 5 | 5 | 5 | 2 | 4 | 9 | 5 | 2 | 5 | 4 | 2 | 3 | 2 | 3 | 2 | 1 | 5 |
| 12/14 | *16.5 | 18 | 0 | 0 | 0 | 18 | 36 | 0 | 0 | 0 | 0 | 18 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 11.5 | 62 | 4 | 3 | 3 | 2 | 3 | 5 | 2 | 1 | 3 | 3 | 2 | 2 | 1 | 2 | 1 | 1 | 2 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

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PAGE 1

           WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  CHOTEAU                   TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:   9/ 9/80

                                         PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-------------------------------------------------------------------------------------------------
   9      * 7.1  7 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  10        5.1         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  11       10.0          63   8   0   4   0   4   4  17   0   0   0   0   0   0   0   0   0   0
  12        7.2          83   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  13        8.4          75  13   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  7.5          82   6   3   4   0   1   1   4   0   0   0   0   0   0   0   0   0   0

  14       10.5          50   4  17   0  13  13   4   0   0   0   0   0   0   0   0   0   0   0
  15       10.5          46   4   8  21   4  17   0   0   0   0   0   0   0   0   0   0   0   0
  16       11.4          75   4   0   0   0   0   0   0   0   4   4   8   4   0   0   0   0   0
  17       19.2          25   8   4  17   4   4   0   0   4   0   0   0   8   4   0   4   4  13
  18        8.3          75   8  13   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  19       17.3          17   8  21   0   8   8   0   0   4   4   0  13   8   0   4   4   0   0
  20       13.7          13   8  13  17  17   8  13   8   0   0   4   0   0   0   0   0   0   0

WKLY  AVG=> 13.0         43   7  11   8   7   7   2   1   1   1   1   3   3   1   1   1   1   2

  21       12.2          38   8   8  13   8   8   4   8   4   0   0   0   0   0   0   0   0   0
  22       13.8          29   0   4   8   4  13  25  13   0   0   4   0   0   0   0   0   0   0
  23       10.8          46   0  25  13   0   4   4   8   0   0   0   0   0   0   0   0   0   0
  24       13.3          38  13   4   0   0   4  13   4   8   8   8   0   0   0   0   0   0   0
  25        6.4          92   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  26        6.5          83   8   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  27        7.0         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 10.0         61   4   8   5   2   4   7   5   2   1   2   0   0   0   0   0   0   0

  28        9.5          71   8   4   4   4   4   4   0   0   0   0   0   0   0   0   0   0   0
  29       14.3           8   4  21  13  17   8  13   4  13   0   0   0   0   0   0   0   0   0
  30       21.8           0   4   4   0   4   8  13  13  25   4   4   0   0   4   4   8   4   0
-------------------------------------------------------------------------------------------------
 SEP       11.1          54   5   8   6   4   5   5   4   3   1   1   1   1   0   0   1   0   1

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  0000 HOURS
STARTING DATE:  10/ 1/80

                                                  PERCENTAGE WIND SPEED PROFILE
 DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-------------------------------------------------------------------------------------------------
   1       21.1          8   0   0   4   8   4   4   8  17   8   0  17  21   0   0   0   0   0
   2        7.1         79  13   4   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
   3        6.9         92   0   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   4        9.2         67  13  13   4   0   4   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 12.8        46   6   7   4   6   5   5   4   8   2   1   2   3   1   1   1   1   0

   5       13.2         33   4   8   4   4   4  25   4   8   4   0   0   0   0   0   0   0   0
   6        6.5         71  13   4  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   7        9.2         75   4   4   4   4   4   0   4   0   0   0   0   0   0   0   0   0   0
   8       15.4         21  13   0   8  13  21   8   0   4   0   0   0   4   0   0   4   4   0
   9      *14.0 21 HRS  43  10   5   5   0   0  10   5   5  19   0   0   0   0   0   0   0   0
  10        5.7         88   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  11        7.9         79  13   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 10.3        59   8   5   5   3   4   6   2   2   3   0   0   1   0   0   1   1   0

  12        7.8         83   0   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  13       15.2         17   0  13   8   0  17  21   4  13   0   4   4   0   0   0   0   0   0
  14        8.2         88   0   0   4   0   0   4   0   0   0   0   0   4   0   0   0   0   0
  15       13.8          8   4  17  17   0  25  17  13   0   0   0   0   0   0   0   0   0   0
  16       10.4         42  13   0   4   8   8  13   8   4   0   0   0   0   0   0   0   0   0
  17       12.8         25   4   4   0   8  38  13   0   4   4   0   0   0   0   0   0   0   0
  18       15.6          0   0   4  21   4  13  42  17   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 12.0        38   3   7   9   3  14  15   6   3   1   1   1   1   0   0   0   0   0

  19       11.1         46  13   8   8   8   4   8   0   4   0   0   0   0   0   0   0   0   0
  20        8.2         63   8   8   4   4   0   8   4   0   0   0   0   0   0   0   0   0   0
  21       12.2         63   0   4   4   4   0   0   0   4   8   4   4   0   0   4   0   0   0
  22       15.0          8   8   4   8  13  33   4   4  13   4   0   0   0   0   0   0   0   0
  23        6.5         96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  24        4.8        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  25        6.3         83  13   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  9.2        65   7   4   4   4   5   3   1   3   2   1   1   0   0   1   0   0   0

  26        5.0        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  27        7.2         75  13  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  28        6.9         96   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  29       16.5         17   0   4  13  13  17  13   0   0   4   0  13   8   0   0   0   0   0
  30        6.3         96   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
  31        9.7         67   8   4   0   4  13   4   0   0   0   0   0   0   0   0   0   0   0
-------------------------------------------------------------------------------------------------
 OCT       10.2         59   6   5   5   3   7   6   2   2   2   0   1   1   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
STARTING TIME:  0000 HOURS
STARTING DATE:  11/ 1/80

                                                    PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
   1       13.6          46   4   0   0   4   8   4  17   4   0   8   0   4   0   0   0   0   0

WKLY  AVG=>  9.3         71   4   3   2   3   6   3   2   1   1   1   2   2   0   0   0   0   0

   2       26.3          13   0   4   0   0   0   8   8   4   0   8   8   4   4   0   8  13  17
   3       10.7          54   0   4   8   0  17   4   4   0   0   4   0   4   0   0   0   0   0
   4       13.8          21   0  21  21   4  21   0   0   0   0   4   0   4   0   4   0   0   0
   5       13.7          38   0  13   0   4   8   8   4   4  17   0   4   0   0   0   0   0   0
   6       15.5          29   8   4   0   0  21  13   4   4   0   4   4   0   0   4   0   4   0
   7       25.0           0   4   4   0   4   8   0   8   8   8   8   4   4   4  13  21   0   0
   8       28.3           0   0   0   0   0   8  17  13   4   8   0   0   0   0   4   4   8  33

WKLY  AVG=> 19.0         22   2   7   4   2  12   7   6   4   5   4   3   2   1   4   5   4   7

   9       13.1          38   0   4   8  13  17   0   4   8   4   4   0   0   0   0   0   0   0
  10      *15.6 21 HRS   38   5   5   0  10  10   0   5   5   5   0   0  10   0  10   0   0   0
  11        NO DATA
  12        NO DATA
  13        NO DATA
  14        NO DATA
  15        NO DATA

WKLY  AVG=> 14.4         38   2   4   4  11  13   0   4   7   4   2   0   4   0   4   0   0   0

  16      *12.9 16 HRS   31  13   6   0   6  13  13  13   6   0   0   0   0   0   0   0   0   0
  17       19.4          17   4   8   8   0   8   4   8   4   0   8   8   4   4   4   8   0   0
  18       16.3          25   8  13   0   0  13   4   8  13   0   4   0   4   0   0   8   0   0
  19       18.0          58   0   4   0   0   0   0   0   4   0   0   4   0   0   0   4   0  25
  20       19.6          17  13   8   8   4   8   0   0   4   4   4   4   4   4   0   0   4  13
  21       23.0           4   0   0   4   0  17   4  13  21   4   4   0   0   8   4   8   0   8
  22        9.0          79   0   0   0   0   4   0  13   4   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 16.9         33   5   6   3   1   9   3   8   8   1   3   3   2   3   1   4   1   7

  23        5.4          92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  24        8.5          75   8   0   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0
  25       16.7          21   0  17   4   8  13   8   4   0   0   4   8   0   4   0   4   4   0
  26       12.6          50   8   0   0   4   4   8   8   0   8   8   0   0   0   0   0   0   0
  27       27.0           4   4   4   0   0   8   4   0  13   4  17   0   4   0   0   4  13  21
  28       17.1          29   4   8   4   8   0   0   8   0   8   0   8  13   8   0   0   0   0
  29       12.0          38   8  13   0   8   8   8   4   8   0   4   0   0   0   0   0   0   0

WKLY  AVG=> 14.2         44   5   7   2   5   5   4   4   3   3   5   2   2   2   0   1   2   3

  30       11.5          38   4  13   4  13  13   8   4   4   0   0   0   0   0   0   0   0   0
-----------------------------------------------------------------------------------------------
 NOV       16.2          34   4   6   3   4   9   5   6   5   3   4   2   2   2   2   3   2   5

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE   4
STARTING TIME:  0000 HOURS
STARTING DATE:  12/ 1/80

                                                      PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38  38
-----------------------------------------------------------------------------------------------
    1        7.3         83  17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    2        5.2        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    3        6.1         96   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4        5.0         96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    5        3.2        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    6        4.5        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  6.1         88   4   2   1   2   2   1   1   1   0   0   0   0   0   0   0   0   0

    7       15.0         38   0   8   4   0   4   8   8   4   8   8   0   0   4   4   0   0   0
    8       16.3         29   0  13   4   0   0  21   0   4  13   0   0   8   4   4   0   0   0
    9       18.3         17   4   4  21   0   8   8   0   4   4   0   8   8   0   8   4   0   0
   10       20.7          8   8   0   0   8   8  13   8   0   8  13   8   0   4   0   8   4   0
   11       21.4         17   8   0   8   0   4   4  17   0   4   8   0   4   0   4   4   4  13
   12       13.5         71   0   4   0   0   0   4   0   0   0   0   0   0   0   0   0   0  21
   13        8.3         71  13   4   0   4   4   4   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 16.2         36   5   5   5   2   4   9   5   2   5   4   2   3   2   3   2   1   5

   14      *16.5 11 HRS  18   0   0   0  18  36   0   0   0   0  18   9   0   0   0   0   0   0
   15       NO DATA
   16       NO DATA
   17       NO DATA
   18       NO DATA
   19       NO DATA
   20       NO DATA

WKLY  AVG=> 16.5         18   0   0   0  18  36   0   0   0   0  18   9   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  DEC       11.5         62   4   3   3   2   3   5   2   1   3   3   2   2   1   2   1   1   2

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

## WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: CHOTEAU
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 9/ 9/80

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 9/13 | * 7.55 | | | 38 |
| 9/20 | 12.98 | | | 250 |
| 9/27 | 10.01 | | | 91 |
| SEP | 11.1 | 889.5 | 58.0 | 162 |
| 10/ 4 | 12.85 | | | 225 |
| 10/11 | 10.27 | | | 121 |
| 10/18 | 11.97 | | | 135 |
| 10/25 | 9.17 | | | 89 |
| OCT | 10.2 | 892.2 | 49.0 | 116 |
| 11/ 1 | 9.31 | | | 102 |
| 11/ 8 | 19.04 | | | 700 |
| 11/10 | *14.35 | | | 280 |
| 11/22 | 16.88 | | | 595 |
| 11/29 | 14.18 | | | 397 |
| NOV | 16.2 | 890.8 | 39.4 | 510 |
| 12/ 6 | 6.11 | | | 26 |
| 12/13 | 16.20 | | | 518 |
| 12/14 | *16.46 | | | 332 |
| DEC | 11.5 | 891.9 | 23.8 | 286 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# WEEKLY & MONTHLY WIND DIRECTION PROFILE

Note: The wind direction values read from the strip charts were interpreted as specified by the manufacturer, i.e., .25 inch of strip chart length representing 15 minutes of direction data. No attempt was made to correct wind direction data to account for recorder motor speed variations as ambient temperature varied. The greatest speed variation we noted amounted to + or - 20.41%. Such a correction was made, however, in the wind speed data. Thus the distribution of the wind direction data in the table below does not correspond to the distribution of wind speed over the same period of time.

LOCATION: CHOTEAU
STARTING TIME: 1700
STARTING DATE: 9/9/80

| WEEK | -PERCENTAGE PROFILE OF WIND DIRECTION- | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ENDING | N | NW | W | SW | S | SE | E | NE |
| 9/13 * | 0 | 20 | 12 | 31 | 32 | 0 | 4 | 0 |
| 9/20 | 37 | 36 | 15 | 11 | 1 | 1 | 0 | 0 |
| 9/27 | 0 | 71 | 14 | 10 | 5 | 0 | 0 | 0 |
| SEP | 14 | 45 | 14 | 16 | 10 | 0 | 0 | 0 |
| 10/4 | 0 | 67 | 20 | 9 | 3 | 0 | 0 | 0 |
| 10/11 * | 0 | 54 | 21 | 20 | 5 | 0 | 0 | 0 |
| 10/18 | 0 | 53 | 15 | 28 | 4 | 0 | 0 | 0 |
| 10/25 | 0 | 44 | 17 | 28 | 11 | 0 | 0 | 0 |
| OCT | 0 | 55 | 18 | 21 | 6 | 0 | 0 | 0 |
| 11/1 | 0 | 75 | 18 | 5 | 2 | 0 | 0 | 0 |
| 11/8 * | 0 | 91 | 7 | 1 | 0 | 0 | 0 | 0 |
| 11/15 * | - | - | - | - | - | - | - | - |
| 11/22 * | 0 | 78 | 11 | 10 | 1 | 0 | 0 | 0 |
| 11/29 * | 0 | 49 | 19 | 24 | 9 | 0 | 0 | 0 |
| NOV | 0 | 71 | 15 | 11 | 3 | 0 | 0 | 0 |
| 12/6 | 0 | 49 | 23 | 14 | 14 | 0 | 0 | 0 |
| 12/13 * | 0 | 49 | 29 | 13 | 8 | 0 | 0 | 0 |
| DEC | 0 | 49 | 24 | 14 | 13 | 0 | 0 | 0 |
| PERIOD TOT: | 3 | 57 | 17 | 16 | 7 | 0 | 0 | 0 |

* this week contains less than 7 days of direction data

```
PAGE 1

     MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM


LOCATION:  CHOTEAU
DWRC TOWER HEIGHT:  10.0 METERS
NCC TOWER HEIGHT:    6.7 METERS
STARTING TIME:  1600 HOURS
STARTING DATE:   9/ 9/80
                                                   (1.0 = PERFECT SITE/WEATHER STATION CORRELATION)
 WEEK     <-CORRELATION  FACTORS->                     FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S
ENDING   MEAN   MINIMUM   MAXIMUM      <.3  <.6  <.9 <1.2 <1.5 <1.8 <2.1 <2.4 <2.7 <3.0 >3.0
-------------------------------------------------------------------------------------------------


 9/13   *1.00    0.74      1.29         0    0   60    0   40    0    0    0    0    0    0
 9/20    0.85    0.69      1.17         0    0   71   29    0    0    0    0    0    0    0
 9/27    0.97    0.59      1.89         0   14   43   29    0    0   14    0    0    0    0
-------------------------------------------------------------------------------------------------
 SEP     0.94    0.59      1.89         0    5   59   18   14    0    5    0    0    0    0
-------------------------------------------------------------------------------------------------
10/ 4    0.98    0.49      2.11         0   29   43    0   14    0    0   14    0    0    0
10/11    0.91    0.47      1.71         0   14   29   43    0   14    0    0    0    0    0
10/18    1.09    0.64      1.70         0    0   29   43   14   14    0    0    0    0    0
10/25    0.90    0.51      1.83         0   29   29   29    0    0   14    0    0    0    0
-------------------------------------------------------------------------------------------------
 OCT     0.92    0.40      2.11         0   23   32   29    3    6    3    3    0    0    0
-------------------------------------------------------------------------------------------------
11/ 1    0.75    0.40      1.00         0   29   43   29    0    0    0    0    0    0    0
11/ 8    0.98    0.60      1.38         0   14   43    0   43    0    0    0    0    0    0
11/10   *1.27    1.00      1.45         0    0    0   50   50    0    0    0    0    0    0
11/22    0.92    0.63      1.16         0    0   43   57    0    0    0    0    0    0    0
11/29    0.90    0.57      1.15         0   14   43   43    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------------
 NOV     0.96    0.57      1.45         0    8   36   40   16    0    0    0    0    0    0
-------------------------------------------------------------------------------------------------
12/ 6    0.79    0.56      1.31         0   29   43   14   14    0    0    0    0    0    0
12/13    1.01    0.52      2.34         0   14   57   14    0    0    0   14    0    0    0
12/14   *0.90    0.90      0.90         0    0  100    0    0    0    0    0    0    0    0
-------------------------------------------------------------------------------------------------
 DEC     0.89    0.52      2.34         0   21   57    7    7    0    0    7    0    0    0
-------------------------------------------------------------------------------------------------


STUDY
PERIOD   0.93    0.40      2.34         0   14   43   26   10    2    2    2    0    0    0

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.
```

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                 MEAN WIND YEAR


SITE LOCATION: CHOTEAU              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE          AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                   (F)                  (W/M2)
--------------------------------------------------------------------------------------------
 JAN        16.8               887.7                  24.7                  415

 FEB        13.4               887.3                  29.6                  192

 MAR        14.2               884.5                  39.5                  217

 APR        13.6               886.9                  40.2                  238

 MAY        12.7               886.3                  59.4                  174

 JUN        13.3               887.5                  63.6                  205

 JUL        10.7               889.5                  71.4                  112

 AUG        10.9               889.0                  71.2                  115

 SEP        11.5               890.0                  58.2                  131

 OCT        14.3               889.5                  49.2                  263

 NOV        13.3               888.7                  25.2                  251

 DEC        15.0               887.2                  28.9                  353

--------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973       13.3                                                             220
```

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                  MINIMUM WIND YEAR


SITE LOCATION: CHOTEAU              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED      AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)               (MBS)                (F)                  (W/M2)
-------------------------------------------------------------------------------------------
 JAN        12.3              887.7                 6.5                  234

 FEB        13.3              887.1                18.8                  267

 MAR        12.7              884.5                34.7                  216

 APR        12.2              888.8                40.7                  157

 MAY        10.0              886.4                51.5                  104

 JUN        10.6              887.4                62.9                  117

 JUL         8.7              889.5                69.0                   63

 AUG         9.2              889.2                69.5                   71

 SEP         9.5              890.2                62.9                   73

 OCT        10.0              889.3                49.4                  100

 NOV        11.2              888.6                33.4                  114

 DEC        16.5              886.6                34.6                  412

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979       11.3                                                          158
```

```
        MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MAXIMUM WIND YEAR


SITE LOCATION: CHOTEAU            NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
          (MPH)              (MBS)                 (F)                   (W/M2)
------------------------------------------------------------------------------------
 JAN       18.2              883.8                19.8                   633

 FEB       13.6              885.2                33.8                   450

 MAR       16.0              882.2                33.3                   433

 APR       12.3              886.2                47.1                   157

 MAY       13.1              885.5                49.5                   202

 JUN       12.1              886.2                66.9                   141

 JUL       10.8              888.9                72.9                   118

 AUG        9.5              890.6                62.9                    60

 SEP       10.0              892.3                54.8                   104

 OCT       12.4              891.6                51.4                   180

 NOV       14.3              888.3                38.7                   264

 DEC       18.3              885.5                32.5                   509

------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974      13.8                                                          267
```

```
        MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                               MEAN WIND YEAR

SITE LOCATION: CHOTEAU            NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                     PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN    16.6     23   3   5   4   2   8   8  10   9   7   7   7   1   4   2   1   1   0   0

 FEB    13.4     30   5   9   8   6   9  11   8   5   2   4   2   0   0   0   0   0   0   0

 MAR    14.2     23   6  12   7   6   7  14  10   4   4   2   2   1   1   0   0   0   0   0

 APR    13.6     34   6  10   5   8   4  10   8   3   3   1   2   2   1   0   2   0   0   0

 MAY    12.7     36   6  14   4   8   6  10   4   4   3   2   2   0   1   0   0   0   0   0

 JUN    13.3     36   7   8   7   5   8   8   6   4   3   2   3   2   1   0   0   0   0   0

 JUL    10.7     58   5   9   6   3   4   6   3   2   2   0   1   0   0   1   0   0   0   0

 AUG    10.9     49   9   9   7   6   4   5   4   1   1   1   1   1   0   0   0   0   0   0

 SEP    11.5     46   8   8   7   5   4   6   6   2   3   2   1   0   0   0   0   0   0   0

 OCT    14.3     31   4   8   4   7   6  12   8   2   6   3   4   2   1   1   0   0   0   0

 NOV    13.3     36   4  10   6   7   3   8   6   3   8   3   3   1   1   0   1   0   0   0

 DEC    15.0     32   3   4   5   5   4   9   7   5   8   4   5   2   3   1   0   0   1   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973   13.3     36   6   9   6   6   5   9   7   4   4   2   3   1   1   1   0   0   0   0
```

```
            MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                     MINIMUM WIND YEAR


SITE LOCATION: CHOTEAU             NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                         PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN    12.3     42   5   2   3   7   4   9   7   5   5   5   4   1   1   0   0   0   0   0

 FEB    13.3     44   4   5   2   4   4   8   6   6   6   3   1   3   1   1   0   0   0   0

 MAR    12.7     44   4   4   3   6   5  10   9   3   5   4   2   0   0   1   0   0   0   0

 APR    12.2     31  14  12   6   6   3   8   8   3   4   2   1   0   0   0   0   0   0   0

 MAY    10.0     57  10  10   6   5   1   3   3   2   2   1   0   0   0   0   0   0   0   0

 JUN    10.6     56   8   5   5   4   4   6   5   3   2   0   0   0   0   0   0   0   0   0

 JUL     8.7     70   8   5   3   3   3   4   2   1   1   0   0   0   0   0   0   0   0   0

 AUG     9.2     65   9   6   5   3   2   3   4   1   0   1   0   0   0   0   0   0   0   0

 SEP     9.5     64   7   9   2   4   3   5   2   1   1   1   0   0   0   0   0   0   0   0

 OCT    10.0     56   7   9   4   3   3   6   6   3   3   0   0   0   0   0   0   0   0   0

 NOV    11.2     43   7  11   6   7   8   9   4   3   2   0   0   0   0   0   0   0   0   0

 DEC    16.5     23   3   8   7   7   3   9   7   7   9   3   5   2   2   2   2   1   1   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979   11.3     50   7   7   4   5   3   7   5   3   3   2   1   1   0   0   0   1   0   1
```

```
           MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                 MAXIMUM WIND YEAR

SITE LOCATION: CHOTEAU              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.93
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                      PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED   <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
------------------------------------------------------------------------------------------

 JAN    18.2    22   3   5   4   5   3  11   7   5   8   4   7   3   2   3   2   2   1   3

 FEB    18.6    11   2   6   4   6   5  13  12   7  13   6   7   3   2   2   1   0   0   0

 MAR    16.0    28   4   8   1   7   5  11   7   5   6   4   2   4   2   2   0   0   1   2

 APR    12.3    40   3  15   5   7   6   7   6   3   4   2   2   0   0   0   0   0   0   0

 MAY    13.1    38   4  10   2   8   6  12   7   3   3   2   3   1   1   0   0   0   0   0

 JUN    12.1    43   8  12   3   5   5  11   3   2   4   2   0   0   1   0   0   0   0   0

 JUL    10.8    54   3  12   4   6   3   8   3   1   2   1   2   1   0   0   0   0   0   0

 AUG     9.5    61   5  11   4   8   4   4   2   0   1   0   0   0   0   0   0   0   0   0

 SEP    10.0    60   5   8   4   5   3   4   4   2   2   2   0   0   0   0   0   0   0   0

 OCT    12.4    41   5   8   5   7   7   9   7   1   3   4   2   1   0   0   0   0   0   0

 NOV    14.3    31   4   9   3   6   4  13   8   5   7   3   3   3   1   0   0   0   0   0

 DEC    18.3    15   4   6   6   5   3  15   7   6   8   5   4   4   4   3   3   1   1   0

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974   13.8    37   4   9   4   6   4  10   6   3   5   3   3   2   1   1   1   0   0   0
```

## APPENDIX I

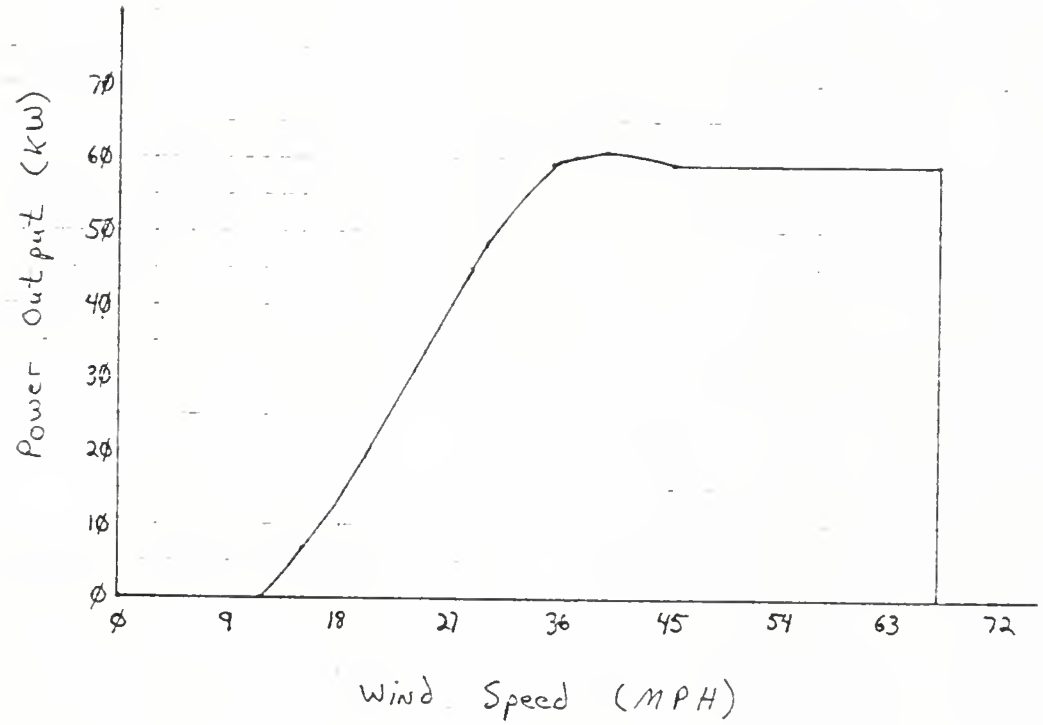
### Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon, Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

# APPENDIX II

Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
Wind Speed Versus Generator kWh Output



## APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3 Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5 Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. Decide whether or not your proposed investment warrants a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   b) the total amount of your proposed investment.
      i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
      ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
      iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2 Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.
3. Look over the information you have collected, and, if you still want

to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.

4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   c) Complete warranty information.
   d) Complete information for utility/home electric interface connection.
   e) Maintenance schedules and their costs.
   f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

III Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

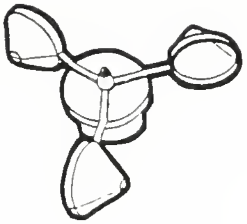
Then, here, in general, are the steps to getting those first kilowatts flowing:

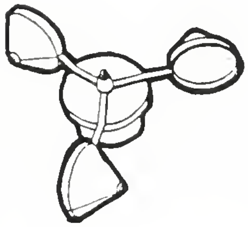
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.
4) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as

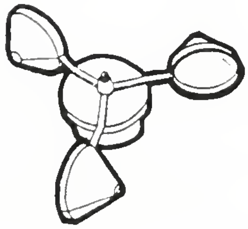
solid as you can make it

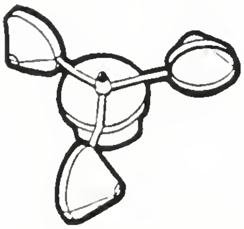
5) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

12/30/83









# Survey of Wind Power
# at
## The Waller Place, Circle, MT
March 26, 1981 - July 18, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #DSR-3 at the Helen and Gordon Waller place near Circle, Montana from March 26, 1981 to July 18, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensors used in the system which gathered this data. The system includes: a model A11-132 dual strip chart recorder housed inside a model A95-003 plastic case; a model A75-104 4-pole cup anemometer; a model A75-301 wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensors to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operational specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operational specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH
Temperature range -60 to 200 degrees F.

The operational specifications for the model A11-132 strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The strip chart recorder records a wind speed and direction reading every two seconds by making a mark on the pressure sensitive strip chart paper as it crosses a metal plate. To make the mark, an impact bar strikes the top side of the meter needles, one for wind speed and one for wind direction, which then touch the sensitive paper.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On December 18, 1980, under contract with DNRC, Gunderson Consulting installed wind monitoring system #DSR-3 at the Helen and Gordon Waller farm northwest of Circle, Montana (mailing address: Circle, MT, 59215). Between the date of installation and July 18, 1981, the Wallers charged the batteries, changed the rolls of strip chart paper as they were filled, and mailed the filled strip charts to Gunderson Consulting to be reviewed for signs of equipment malfunction. Gunderson Consulting then delivered them to the Renewable Energy Bureau of DNRC. In June 1982 the Department contracted with Gunderson Consulting to analyze and summarize the data.

During the seven-month monitoring period, seven strip charts were filled with data. Gunderson Consulting analyzed the four which were filled when the temperature range was most favorable to proper operation of the recorder. Thus, the monitoring period is from December through July while the study period is March through July.

To locate the monitoring site, drive into Circle on State Highway 200 and turn north at the Mini-Mall onto State Secondary 252. Follow 252 north and west for 12 miles, then turn north for another six miles, then turn west for one mile until the road ends at the Waller farm.

## Equipment History

On July 1, 1981, Gordon Waller discovered that the needle for the wind direction channel of the strip chart recorder was broken off and reported it to DNRC. The present analysis of the strip charts reveals that no wind direction data had been recorded since 8 p.m. (2000 h.) on May 13, 1981. In October, 1981, the recorder was shipped to the manufacturer to replace the broken needle.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computed calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

The weekly and monthly wind direction summaries were prepared manually from the marks made by the wind direction needle on the eight direction tracks on strip chart. (One track on the strip chart is assigned to each octant of the compass--N, NE, E, SE, etc.). For each summary period, the operator counted the number of quarter-inch (15-minute) marks in each direction track on the strip chart at the same time he digitized the wind speed curve. He then divided the total number of marks in each direction track by the total number of marks in all direction tracks during the same period to derive the percentage of time the wind blew in each octant for the summary period.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Miles City) is at 12.19 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station at the Miles City airport. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three- hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most

useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P = (1/2)pKV^{3}$$

where P = wind power density
p = air density
V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms
Note that air density p is defined as: p = A/(RT)
where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## Data Use

First, refer to Appendix I and compare the average wind power density at your monitored site to the densities at other sites in the state. (Comparison of wind power densities provides the best picture of how one site's potential compares with others.)

Next, estimate the power output you might expect from a particular wind generator installed at your site. You will need the generator manufacturer's wind-speed-versus-power output graph, or "power characteristic curve" as it is sometimes called (Appendix II is such a curve for a Holec Windmatic model 14S wind generator), and the "Average Monthly and Yearly Wind Speed and Percentage Speed Profile" of your site. Follow the procedure in the example below to estimate yearly (or monthly) generator ouput. Then, to calculate a dollar value of the power that generator might generate under the conditions at your site, multiply the estimated generator output by the value of the electricity you would be displacing.

In the following example use the Power Characteristic Curve in Appendix II and the following annual wind speed percentage spectrum:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these annual percentage figures into the number of hours per year the wind blew in each bracket. Multiply the percent value from the percentage spectrum by the number of hours in a year, (365 X 24 = 8,760 hours in a year). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds in the less-than-10-MPH bracket. For the second bracket, the wind blew .05 X 8,760 = 438 hours at speeds between 10 and 10.99 MPH. This process can be continued for each bracket of the spectrum. The final result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

The next step is to assign a MPH value to the middle of each velocity bracket and then use the Power Characteristic Curve to find the generator's power output for each associated midpoint speed. The midpoint of each velocity bracket has been rounded to the nearest MPH for convenience below.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KW) FROM POWER CHARACTERISTIC CURVE

To do the final step, multiply the number of hours in each bracket by the generator output and add all of the ouputs together to obtain the total generator output for the period, which, in this example, is one year.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

In this example, the generator output for the total period (one year) is 51,771 KWh. To find the value of the electricity which would theoretically be displaced by this generator at a site with this wind speed profile, multiply the value of the electricity by the total production. In this example we will use $.0625/KWh for the unit value of displaced electricity; therefore, the total value of the displaced electricity would be $3,235.69 per year.

However, many factors other than the cost of the generator and the value of displaced electricity must be considered to make a realistic evaluation of the economics of wind electric generation at your site--factors such as: the one-time costs of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for the foundation, freight charges, fees for inspection and system checkout, and the continuous expenses of insurance, operation and maintenance. The following breakdown gives a broad guideline for the cost of a larges scale wind development:

Generator and Blade Assembly - 57%
Tower and Site Access - 11%
Foundation/Site Preparation - 9%
Operations/Maintenance - 9%
Assembly/Checkout - 8%
Other - 4%
Equipment Transportation - 2%

Source: from publication SERI/SP-732-728 pulblished by the Solar Energy Research Institute, October 1980.

Not all of these costs will apply in the same percentages to every installation, but the likelihood is always a good that other costs will occur in their place.

As a rule of thumb, a wind site that has a wind power density of over 200 watts per square meter and has a minimum average wind speed of 12 MPH for at least six months per year should considered for wind development. The final decision to develop your wind potential is an investment decision which deserves the same degree of careful analysis as you give any other development investment. Appendix III is a suggested wind electric generation development guide.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

The multi-page summary titled "Wind Speed Summary (in MPH) and Percentage Spectrum" contains daily, weekly and monthly average wind speeds and a wind speed percentage spectrum for each speed average. This summary should be interpreted in the same manner as the preceeding summary.

On the summary sheet titled, "Weekly and Monthly Average Wind Power Density," the last column gives the weekly and monthly average wind power density at the site during the monitoring period. The average wind speed in mph is also shown.

The summary sheet titled, "Weekly & Monthly Wind Direction Profile," gives the approximate percent of time the wind was blowing in each of the 8 different compass directions during the monitoring period. (Please note that these directions are based on magnetic North, not geographic North.)

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors" for each time period, which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these

sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But while the preceeding summaries estimate wind power density, these estimate wind speed averages--the mean, minimum and maximum monthly and yearly average wind speeds likely to occur at the site--and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: CIRCLE TOWER HEIGHT: 10 METERS
STARTING TIME: 1100 HOURS
STARTING DATE: 3/26/81

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >3 |
| 3/28 | *16.1 | 20 | 10 | 13 | 11 | 8 | 8 | 3 | 2 | 7 | 5 | 7 | 3 | 2 | 0 | 2 | 0 | 0 | |
| MAR | 15.2 | 28 | 11 | 8 | 8 | 5 | 5 | 5 | 5 | 6 | 4 | 8 | 5 | 2 | 0 | 1 | 0 | 0 | |
| 4/ 4 | 13.5 | 39 | 10 | 5 | 6 | 3 | 5 | 10 | 7 | 4 | 1 | 4 | 5 | 2 | 1 | 0 | 0 | 0 | |
| 4/11 | 15.7 | 21 | 10 | 7 | 5 | 6 | 8 | 6 | 8 | 8 | 8 | 5 | 3 | 2 | 1 | 1 | 0 | 0 | |
| 4/18 | 13.0 | 39 | 7 | 7 | 6 | 7 | 7 | 6 | 6 | 5 | 3 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | |
| 4/25 | 16.8 | 22 | 5 | 5 | 3 | 2 | 13 | 8 | 9 | 5 | 8 | 7 | 7 | 5 | 2 | 0 | 0 | 0 | |
| APR | 14.5 | 31 | 8 | 6 | 5 | 5 | 9 | 7 | 7 | 6 | 5 | 4 | 3 | 3 | 1 | 1 | 0 | 0 | |
| 5/ 2 | 13.6 | 32 | 10 | 7 | 7 | 5 | 11 | 6 | 6 | 7 | 3 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | |
| 5/ 9 | 16.6 | 23 | 5 | 7 | 6 | 4 | 10 | 13 | 5 | 5 | 3 | 4 | 7 | 3 | 4 | 0 | 1 | 1 | |
| 5/16 | 17.8 | 16 | 8 | 9 | 5 | 5 | 7 | 6 | 8 | 5 | 9 | 4 | 7 | 2 | 2 | 4 | 2 | 1 | |
| 5/23 | 16.3 | 14 | 5 | 8 | 6 | 6 | 14 | 15 | 13 | 5 | 2 | 2 | 2 | 5 | 3 | 1 | 0 | 0 | |
| 5/30 | 11.3 | 38 | 14 | 17 | 6 | 10 | 4 | 2 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| MAY | 15.3 | 23 | 8 | 10 | 6 | 6 | 9 | 9 | 8 | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | |
| 6/ 6 | 11.9 | 30 | 7 | 16 | 11 | 10 | 13 | 7 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 6/13 | 13.4 | 35 | 8 | 8 | 6 | 4 | 13 | 9 | 2 | 2 | 2 | 4 | 2 | 1 | 1 | 1 | 1 | 0 | |
| 6/20 | 13.4 | 33 | 6 | 8 | 11 | 7 | 7 | 5 | 9 | 4 | 1 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | |
| 6/27 | 11.6 | 40 | 8 | 6 | 10 | 8 | 12 | 8 | 5 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | |
| JUN | 12.4 | 35 | 8 | 10 | 9 | 7 | 11 | 7 | 5 | 2 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | |
| 7/ 4 | 10.5 | 50 | 8 | 13 | 7 | 6 | 7 | 4 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 7/11 | 12.6 | 37 | 11 | 8 | 5 | 11 | 8 | 5 | 6 | 4 | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | |
| 7/18 | *11.9 | 40 | 5 | 13 | 9 | 8 | 7 | 4 | 5 | 3 | 4 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | |
| JUL | 11.8 | 42 | 8 | 11 | 7 | 9 | 6 | 4 | 5 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

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PAGE 1

            WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM

LOCATION:  CIRCLE                  TOWER HEIGHT:  10 METERS
STARTING TIME:  1100 HOURS
STARTING DATE:   3/26/81

                                            PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >3
-----------------------------------------------------------------------------------------------
   26     *24.6 13 HRS   0   0   0   0   0   0   8   0  23   8  31  15   8   0   8   0   0
   27      14.3          4   4  21  21  17  13   4   4   4   8   0   0   0   0   0   0   0
   28       9.4         46  21  13   8   4   8   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 16.1        20  10  13  11   8   8   3   2   7   5   7   3   2   0   2   0   0

   29       8.9         63  17   8   4   4   4   0   0   0   0   0   0   0   0   0   0   0
   30      16.3         21  13   4   8   4   0   8  13   4   4   8   8   4   0   0   0   0
   31      17.7         21   4   0   0   0   4  13  13  13   4  17  13   0   0   0   0   0
-----------------------------------------------------------------------------------------------
  MAR      15.2         28  11   8   8   5   5   5   5   6   4   8   5   2   0   1   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

PAGE 2
STARTING TIME: 0000 HOURS
STARTING DATE: 4/ 1/81

| DATE | AVG WIND SPD | PERCENTAGE WIND SPEED PROFILE <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13.2 | 29 | 17 | 0 | 13 | 4 | 4 | 21 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 12.5 | 33 | 4 | 13 | 4 | 8 | 13 | 17 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 7.5 | 83 | 4 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 18.1 | 21 | 8 | 4 | 4 | 0 | 8 | 8 | 4 | 4 | 0 | 4 | 13 | 13 | 8 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 13.5 | 39 | 10 | 5 | 6 | 3 | 5 | 10 | 7 | 4 | 1 | 4 | 5 | 2 | 1 | 0 | 0 | 0 | 0 |
| 5 | 15.0 | 25 | 4 | 0 | 0 | 13 | 17 | 4 | 17 | 17 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| 6 | 23.5 | 4 | 4 | 4 | 0 | 4 | 0 | 4 | 8 | 4 | 8 | 17 | 13 | 13 | 8 | 8 | 0 | 0 | 0 |
| 7 | 10.5 | 42 | 13 | 8 | 8 | 17 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 11.4 | 33 | 25 | 8 | 8 | 0 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 17.1 | 21 | 0 | 13 | 4 | 0 | 4 | 4 | 13 | 13 | 21 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 12.3 | 21 | 25 | 13 | 13 | 8 | 4 | 0 | 13 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 20.2 | 4 | 0 | 0 | 0 | 0 | 17 | 13 | 0 | 17 | 29 | 17 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 15.7 | 21 | 10 | 7 | 5 | 6 | 8 | 6 | 8 | 8 | 8 | 5 | 3 | 2 | 1 | 1 | 0 | 0 | |
| 12 | 14.6 | 21 | 8 | 0 | 0 | 13 | 21 | 8 | 4 | 21 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 13 | 7.8 | 75 | 8 | 8 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 14 | 12.8 | 50 | 4 | 4 | 0 | 4 | 4 | 8 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 15 | 10.3 | 50 | 8 | 17 | 13 | 0 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 16 | 17.0 | 33 | 4 | 0 | 0 | 17 | 0 | 4 | 0 | 4 | 0 | 4 | 8 | 17 | 4 | 4 | 0 | 0 | |
| 17 | 10.5 | 38 | 13 | 21 | 8 | 13 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 18 | 18.2 | 4 | 0 | 0 | 17 | 0 | 8 | 17 | 25 | 0 | 21 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | |
| WKLY AVG=> | 13.0 | 39 | 7 | 7 | 6 | 7 | 7 | 6 | 6 | 5 | 3 | 2 | 1 | 2 | 1 | 1 | 0 | 0 | |
| 19 | 22.1 | 0 | 0 | 0 | 0 | 4 | 8 | 13 | 13 | 4 | 21 | 17 | 13 | 8 | 0 | 0 | 0 | 0 | |
| 20 | 22.4 | 0 | 0 | 13 | 0 | 4 | 0 | 8 | 0 | 4 | 25 | 13 | 25 | 8 | 0 | 0 | 0 | 0 | |
| 21 | 21.9 | 0 | 0 | 4 | 4 | 0 | 25 | 4 | 8 | 8 | 4 | 4 | 8 | 17 | 13 | 0 | 0 | 0 | |
| 22 | 13.9 | 25 | 4 | 0 | 0 | 4 | 29 | 17 | 17 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 23 | 12.7 | 46 | 0 | 4 | 8 | 4 | 8 | 8 | 8 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 24 | 15.3 | 21 | 17 | 4 | 0 | 0 | 17 | 0 | 17 | 13 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 25 | * 9.3 23 HRS | 61 | 13 | 13 | 9 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| WKLY AVG=> | 16.8 | 22 | 5 | 5 | 3 | 2 | 13 | 8 | 9 | 5 | 8 | 7 | 7 | 5 | 2 | 0 | 0 | 0 | |
| 26 | 10.6 | 63 | 4 | 4 | 4 | 4 | 4 | 4 | 8 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 27 | 8.6 | 71 | 13 | 0 | 4 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 28 | 18.6 | 4 | 13 | 8 | 8 | 13 | 17 | 0 | 4 | 4 | 4 | 0 | 8 | 0 | 0 | 4 | 8 | 4 | |
| 29 | 15.6 | 13 | 13 | 13 | 13 | 0 | 4 | 4 | 8 | 25 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 30 | 10.6 | 46 | 17 | 13 | 4 | 4 | 13 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| APR | 14.5 | 31 | 8 | 6 | 5 | 5 | 9 | 7 | 7 | 6 | 5 | 4 | 3 | 3 | 1 | 1 | 0 | 0 | |

NOTE: * INDICATES THAT A DAILY AVERAGE IS FOR FEWER THAN 24 HOURS. THE TOTAL NUMBER OF HOURS IS GIVEN.

PAGE 3
STARTING TIME: 0000 HOURS
STARTING DATE: 5/ 1/81

PERCENTAGE WIND SPEED PROFILE

| DATE | AVG WIND SPD | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16.6 | 4 | 8 | 4 | 8 | 4 | 13 | 21 | 4 | 21 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 14.6 | 21 | 0 | 8 | 8 | 8 | 21 | 8 | 17 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 13.6 | 32 | 10 | 7 | 7 | 5 | 11 | 6 | 6 | 7 | 3 | 2 | 1 | 0 | 0 | 1 | 1 | 1 |
| 3 | 13.9 | 29 | 8 | 4 | 4 | 4 | 8 | 13 | 13 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 11.7 | 38 | 8 | 13 | 8 | 4 | 4 | 17 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 23.2 | 0 | 0 | 0 | 0 | 0 | 8 | 21 | 4 | 4 | 8 | 17 | 21 | 8 | 8 | 0 | 0 | 0 |
| 6 | 28.8 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 4 | 4 | 4 | 8 | 17 | 13 | 17 | 0 | 4 | 8 |
| 7 | 11.4 | 38 | 8 | 17 | 8 | 4 | 13 | 8 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 14.1 | 25 | 13 | 8 | 13 | 4 | 4 | 8 | 4 | 4 | 8 | 0 | 8 | 0 | 0 | 0 | 0 | 0 |
| 9 | 12.9 | 29 | 0 | 4 | 8 | 8 | 33 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 16.6 | 23 | 5 | 7 | 6 | 4 | 10 | 13 | 5 | 5 | 3 | 4 | 7 | 3 | 4 | 0 | 1 | 1 |
| 10 | 16.0 | 0 | 4 | 4 | 13 | 13 | 13 | 25 | 25 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 19.1 | 0 | 4 | 0 | 8 | 4 | 17 | 8 | 25 | 13 | 8 | 0 | 0 | 0 | 8 | 4 | 0 | 0 |
| 12 | 16.9 | 21 | 8 | 4 | 4 | 4 | 4 | 4 | 4 | 13 | 17 | 8 | 8 | 0 | 0 | 0 | 0 | 0 |
| 13 | 10.3 | 46 | 17 | 25 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 10.3 | 46 | 8 | 25 | 8 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 26.5 | 0 | 13 | 4 | 0 | 0 | 4 | 4 | 4 | 0 | 8 | 0 | 13 | 0 | 4 | 21 | 13 | 8 |
| 16 | 25.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 29 | 21 | 25 | 17 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 17.8 | 16 | 8 | 9 | 5 | 5 | 7 | 6 | 8 | 5 | 9 | 4 | 7 | 2 | 2 | 4 | 2 | 1 |
| 17 | 16.1 | 13 | 4 | 13 | 0 | 0 | 4 | 21 | 33 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 22.1 | 0 | 0 | 13 | 4 | 4 | 13 | 8 | 4 | 4 | 0 | 4 | 8 | 17 | 13 | 8 | 0 | 0 |
| 19 | 21.9 | 0 | 0 | 0 | 8 | 0 | 4 | 21 | 13 | 8 | 8 | 8 | 4 | 17 | 8 | 0 | 0 | 0 |
| 20 | 12.2 | 13 | 21 | 25 | 8 | 4 | 25 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 9.8 | 63 | 4 | 4 | 8 | 8 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 16.7 | 0 | 0 | 0 | 8 | 8 | 29 | 21 | 21 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 15.3 | 8 | 4 | 0 | 4 | 17 | 21 | 29 | 13 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 16.3 | 14 | 5 | 8 | 6 | 6 | 14 | 15 | 13 | 5 | 2 | 2 | 2 | 5 | 3 | 1 | 0 | 0 |
| 24 | 10.4 | 38 | 8 | 29 | 4 | 17 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 10.0 | 42 | 25 | 17 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 11.1 | 25 | 25 | 21 | 21 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 8.7 | 54 | 21 | 17 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 16.4 | 4 | 4 | 8 | 4 | 21 | 13 | 4 | 17 | 17 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 14.5 | 21 | 4 | 21 | 4 | 4 | 8 | 8 | 8 | 17 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 8.1 | 83 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 11.3 | 38 | 14 | 17 | 6 | 10 | 4 | 2 | 4 | 5 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 11.1 | 54 | 4 | 8 | 4 | 4 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAY | 15.3 | 23 | 8 | 10 | 6 | 6 | 9 | 9 | 8 | 5 | 4 | 3 | 3 | 2 | 2 | 1 | 1 | 1 |

NOTE: * INDICATES THAT A DAILY AVERAGE IS FOR FEWER THAN 24 HOURS. THE TOTAL NUMBER OF HOURS IS GIVEN.

STARTING TIME: 0000 HOURS
STARTING DATE: 6/ 1/81

| | | PERCENTAGE WIND SPEED PROFILE | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE | AVG WIND SPD | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
| 1 | 15.1 | 0 | 0 | 0 | 17 | 25 | 29 | 21 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 9.7 | 50 | 0 | 25 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 12.9 | 21 | 0 | 25 | 13 | 8 | 21 | 4 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 12.5 | 25 | 4 | 17 | 13 | 13 | 8 | 17 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 10.2 | 33 | 29 | 13 | 13 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 12.1 | 29 | 8 | 25 | 8 | 8 | 8 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 11.9 | 30 | 7 | 16 | 11 | 10 | 13 | 7 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 12.3 | 33 | 0 | 17 | 8 | 4 | 17 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 14.8 | 42 | 8 | 0 | 0 | 4 | 4 | 4 | 0 | 17 | 8 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 17.4 | 46 | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 0 | 4 | 13 | 8 | 4 | 8 | 4 | 4 | 0 | 0 |
| 10 | 11.9 | 29 | 17 | 13 | 4 | 8 | 25 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 10.2 | 50 | 8 | 13 | 21 | 4 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 13.6 | 25 | 17 | 8 | 0 | 4 | 21 | 8 | 4 | 0 | 4 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| 13 | 13.4 | 21 | 8 | 8 | 8 | 4 | 17 | 25 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 13.4 | 35 | 8 | 8 | 6 | 4 | 13 | 9 | 2 | 2 | 2 | 4 | 2 | 1 | 1 | 1 | 1 | 0 | 0 |
| 14 | 13.7 | 13 | 8 | 17 | 25 | 4 | 4 | 4 | 17 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 16.5 | 17 | 8 | 4 | 13 | 0 | 4 | 8 | 17 | 8 | 4 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 14.4 | 25 | 4 | 8 | 4 | 4 | 13 | 13 | 21 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 20.4 | 0 | 4 | 17 | 4 | 0 | 8 | 4 | 8 | 4 | 4 | 21 | 17 | 8 | 0 | 0 | 0 | 0 | 0 |
| 18 | 10.7 | 38 | 17 | 4 | 21 | 8 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 10.2 | 54 | 0 | 4 | 4 | 25 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 8.1 | 88 | 0 | 0 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WKLY AVG=> | 13.4 | 33 | 6 | 8 | 11 | 7 | 7 | 5 | 9 | 4 | 1 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 21 | 15.0 | 21 | 8 | 0 | 8 | 4 | 13 | 13 | 17 | 4 | 4 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 10.6 | 50 | 13 | 4 | 4 | 21 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 13.8 | 17 | 21 | 13 | 4 | 0 | 13 | 21 | 4 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 13.1 | 38 | 4 | 4 | 0 | 8 | 21 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | * 7.5 22 HRS | 77 | 5 | 14 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 9.6 | 58 | 0 | 0 | 25 | 4 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 11.8 | 21 | 8 | 8 | 21 | 17 | 21 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| WKLY AVG=> | 11.6 | 40 | 8 | 6 | 10 | 8 | 12 | 8 | 5 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 11.9 | 29 | 17 | 8 | 13 | 4 | 13 | 8 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 29 | 10.6 | 42 | 8 | 13 | 8 | 4 | 21 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 30 | 8.6 | 63 | 8 | 25 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| JUN | 12.4 | 35 | 8 | 10 | 9 | 7 | 11 | 7 | 5 | 2 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | |

NOTE: * INDICATES THAT A DAILY AVERAGE IS FOR FEWER THAN 24 HOURS. THE TOTAL NUMBER OF HOURS IS GIVEN.

```
PAGE  5
STARTING TIME:  0000 HOURS
STARTING DATE:   7/ 1/81

                                                 PERCENTAGE WIND SPEED PROFILE
 DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
------------------------------------------------------------------------------------------------
   1       15.7          0   0   4  17  25  13  17  13   8   4   0   0   0   0   0   0   0   0
   2        9.1         63   8  25   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   3        9.2         75   4   8   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   4        8.1         79  13   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 10.5        50   8  13   7   6   7   4   2   1   1   1   0   0   0   0   0   0   0

   5        9.7         54  21   4  17   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   6       14.5         21   0   8   8  13  13   8  21   8   0   0   0   0   0   0   0   0   0
   7       18.5         21   4   4   0   4   4  13  13   8   0  13   0   8   4   0   4   0   0
   8       14.6         21   0   8   0  21  13  17   8   4   4   0   4   0   0   0   0   0   0
   9        8.7         67  21   4   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0
  10       12.7         13  21  17   4  13  25   0   0   8   0   0   0   0   0   0   0   0   0
  11        9.3         63   8   8   4  17   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 12.6        37  11   8   5  11   8   5   6   4   1   2   1   1   1   0   1   0   0

  12       11.8         50   4   8   0   8   8  13   0   0   4   4   0   0   0   0   0   0   0
  13       19.3          0   0   8   4   8  21   0   8  13  21   8   4   0   4   0   0   0   0
  14       10.7         42   8   4  25   8  13   0   0   0   0   0   0   0   0   0   0   0   0
  15       13.1         29   0  21   0   4   4  13  25   4   0   0   0   0   0   0   0   0   0
  16        8.9         58   4  29   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  17       10.0         54   8   4  17  17   0   0   0   0   0   0   0   0   0   0   0   0   0
  18      * 9.2 16 HRS  50  13  19  13   6   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 11.9        40   5  13   9   8   7   4   5   3   4   2   1   0   1   0   0   0   0

------------------------------------------------------------------------------------------------
  JUL      11.8         42   8  11   7   9   6   4   5   3   2   1   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

## WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: CIRCLE TOWER HEIGHT: 10 METERS
STARTING TIME: 1100 HOURS
STARTING DATE: 3/26/81

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 3/28 | *16.1 | | | 269 |
| MAR | 15.2 | 921.4 | 40.7 | 267 |
| 4/ 4 | 13.5 | | | 233 |
| 4/11 | 15.7 | | | 309 |
| 4/18 | 13.0 | | | 199 |
| 4/25 | 16.8 | | | 371 |
| APR | 14.5 | 921.0 | 51.3 | 268 |
| 5/ 2 | 13.6 | | | 219 |
| 5/ 9 | 16.6 | | | 402 |
| 5/16 | 17.8 | | | 457 |
| 5/23 | 16.3 | | | 317 |
| 5/30 | 11.3 | | | 104 |
| MAY | 15.3 | 919.7 | 57.1 | 308 |
| 6/ 6 | 11.9 | | | 106 |
| 6/13 | 13.4 | | | 205 |
| 6/20 | 13.4 | | | 176 |
| 6/27 | 11.6 | | | 116 |
| JUN | 12.4 | 920.0 | 63.9 | 150 |
| 7/ 4 | 10.5 | | | 80 |
| 7/11 | 12.6 | | | 162 |
| 7/18 | *11.9 | | | 136 |
| JUL | 11.8 | 922.4 | 75.1 | 134 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

## WEEKLY & MONTHLY WIND DIRECTION PROFILE

Note: The wind direction values read from the strip charts were interpreted as specified by the manufacturer, i.e., .25 inch of strip chart length representing 15 minutes of direction data. No attempt was made to correct wind direction data to account for recorder motor speed variations as ambient temperature varied. The greatest speed variation we noted amounted to + or - 1.09%. However, a correction was made in the wind speed data. Thus the distribution of the wind direction data in the table below does not correspond to the distribution of wind speed over the same period of time.

LOCATION: CIRCLE
STARTING TIME: 1100
STARTING DATE: 3/26/81

| WEEK | | | -PERCENTAGE PROFILE OF WIND DIRECTION- | | | | | |
|---|---|---|---|---|---|---|---|---|
| ENDING | N | NW | W | SW | S | SE | E | NE |
| 3/28 * | 20 | 16 | 3 | 6 | 7 | 28 | 6 | 14 |
| MAR | 20 | 16 | 3 | 6 | 7 | 28 | 6 | 14 |
| 4/4 | 9 | 52 | 21 | 6 | 9 | 3 | 0 | 0 |
| 4/11 | 3 | 24 | 31 | 18 | 7 | 15 | 2 | 0 |
| 4/18 | 27 | 18 | 4 | 15 | 17 | 8 | 4 | 7 |
| 4/25 * | 13 | 37 | 14 | 9 | 12 | 15 | 0 | 0 |
| APR | 13 | 33 | 18 | 12 | 11 | 10 | 2 | 2 |
| 5/2 | 26 | 34 | 12 | 5 | 9 | 8 | 1 | 5 |
| 5/9 | 7 | 9 | 7 | 7 | 10 | 35 | 13 | 12 |
| 5/16 * | 8 | 7 | 11 | 20 | 13 | 9 | 17 | 16 |
| MAY | 14 | 18 | 10 | 9 | 10 | 18 | 10 | 10 |
| PERIOD TOT: | 14 | 26 | 14 | 11 | 11 | 14 | 5 | 6 |

due to sensor malfunction, there is no direction data after 2000 hrs on 5/14/81

* this week contains less than 7 days of direction data;
the direction sensor was aligned with the magnetic north pole

MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: CIRCLE
DNRC TOWER HEIGHT: 10.0 METERS
NCC TOWER HEIGHT: 12.2 METERS
STARTING TIME: 1000 HOURS
STARTING DATE: 3/26/81

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION | FACTORS-> | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 3/28 | *1.22 | 1.00 | 1.43 | 0 | 0 | 0 | 33 | 67 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 1.19 | 1.00 | 1.43 | 0 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4/ 4 | 1.20 | 0.94 | 1.48 | 0 | 0 | 0 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4/11 | 1.53 | 1.00 | 2.20 | 0 | 0 | 0 | 14 | 57 | 14 | 0 | 14 | 0 | 0 | 0 |
| 4/18 | 1.30 | 0.84 | 1.48 | 0 | 0 | 14 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4/25 | 1.24 | 0.94 | 1.45 | 0 | 0 | 0 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 |
| APR | 1.30 | 0.84 | 2.20 | 0 | 0 | 3 | 27 | 63 | 3 | 0 | 3 | 0 | 0 | 0 |
| 5/ 2 | 1.17 | 0.92 | 1.33 | 0 | 0 | 0 | 57 | 43 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/ 9 | 1.41 | 0.94 | 1.64 | 0 | 0 | 0 | 29 | 14 | 57 | 0 | 0 | 0 | 0 | 0 |
| 5/16 | 1.65 | 1.00 | 2.40 | 0 | 0 | 0 | 14 | 14 | 43 | 14 | 14 | 0 | 0 | 0 |
| 5/23 | 1.26 | 1.00 | 1.41 | 0 | 0 | 0 | 29 | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5/30 | 1.30 | 1.00 | 1.57 | 0 | 0 | 0 | 29 | 57 | 14 | 0 | 0 | 0 | 0 | 0 |
| MAY | 1.39 | 0.94 | 2.40 | 0 | 0 | 0 | 26 | 42 | 26 | 3 | 3 | 0 | 0 | 0 |
| 6/ 6 | 1.22 | 0.99 | 1.35 | 0 | 0 | 0 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/13 | 1.51 | 1.00 | 2.14 | 0 | 0 | 0 | 0 | 86 | 0 | 0 | 14 | 0 | 0 | 0 |
| 6/20 | 1.17 | 0.81 | 1.46 | 0 | 0 | 14 | 57 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6/27 | 1.23 | 0.99 | 1.42 | 0 | 0 | 0 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUN | 1.28 | 0.81 | 2.14 | 0 | 0 | 3 | 37 | 57 | 0 | 0 | 3 | 0 | 0 | 0 |
| 7/ 4 | 1.34 | 0.91 | 1.71 | 0 | 0 | 0 | 29 | 57 | 14 | 0 | 0 | 0 | 0 | 0 |
| 7/11 | 1.31 | 1.00 | 1.48 | 0 | 0 | 0 | 29 | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/18 | 1.45 | 1.00 | 1.85 | 0 | 0 | 0 | 0 | 71 | 14 | 14 | 0 | 0 | 0 | 0 |
| JUL | 1.38 | 0.91 | 1.85 | 0 | 0 | 0 | 17 | 67 | 11 | 6 | 0 | 0 | 0 | 0 |
| STUDY PERIOD | 1.33 | 0.81 | 2.40 | 0 | 0 | 2 | 29 | 56 | 10 | 2 | 3 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

The following mean and minimum projected wind years are identical because of these circumstances: The thirty-year average annual wind speed at the FAA Station at the Municipal Airport is 9.7 MPH. During the 10-year period (1970 to 1979) used as the representative data period in this study, the minimum annual wind speed was 10.1 MPH (1979). Because there is significant variation between NCC's thirty-year average wind speed and the 10-year minimum, we used the lower value to represent both the minimum and the mean wind year. By doing this, we avoided the upward skew which the larger value would have produced.

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                  MEAN WIND YEAR

SITE LOCATION: CIRCLE              NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE    AVG WIND POWER DENSITY
           (MPH)              (MBS)                (F)                  (W/M2)
------------------------------------------------------------------------------------------
 JAN        10.9              925.2                0.2                   146

 FEB        13.6              921.8                8.0                   271

 MAR        13.6              921.8               29.8                   236

 APR        15.1              919.7               41.4                   320

 MAY        14.3              920.8               53.7                   260

 JUN        14.2              921.4               67.3                   238

 JUL        11.8              922.1               74.6                   146

 AUG        12.5              921.1               72.0                   174

 SEP        12.5              922.5               65.7                   159

 OCT        12.5              921.4               50.7                   176

 NOV        11.6              924.8               29.8                   160

 DEC        12.7              922.1               29.1                   222

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979       12.9                                                         208
```

```
         MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MINIMUM WIND YEAR

SITE LOCATION: CIRCLE            NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                 (F)                  (W/M2)
------------------------------------------------------------------------------------------
 JAN       10.9               925.2                 0.2                   146

 FEB       13.6               921.8                 8.0                   271

 MAR       13.6               921.8                29.8                   236

 APR       15.1               919.7                41.4                   320

 MAY       14.3               920.8                53.7                   260

 JUN       14.2               921.4                67.3                   238

 JUL       11.8               922.1                74.6                   146

 AUG       12.5               921.1                72.0                   174

 SEP       12.5               922.5                65.7                   159

 OCT       12.5               921.4                50.7                   176

 NOV       11.6               924.8                29.8                   160

 DEC       12.7               922.1                29.1                   222

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979      12.9                                                           208
```

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                 MAXIMUM WIND YEAR

SITE LOCATION: CIRCLE             NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/76
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                 (F)                   (W/M2)
-------------------------------------------------------------------------------------------
 JAN        14.4              923.8                18.6                    303

 FEB        15.4              919.1                32.4                    332

 MAR        16.1              918.1                32.5                    421

 APR        16.3              920.1                48.6                    366

 MAY        14.4              921.1                59.1                    300

 JUN        16.0              918.7                65.6                    335

 JUL        14.1              921.1                76.4                    238

 AUG        14.7              921.8                74.1                    291

 SEP        12.3              923.1                62.9                    177

 OCT        12.9              924.5                44.2                    210

 NOV        12.1              926.5                29.4                    201

 DEC        13.9              921.8                25.5                    256

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1976       14.4                                                           286
```

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                   MEAN WIND YEAR

SITE LOCATION: CIRCLE             NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                        PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
---------------------------------------------------------------------------------------------

 JAN    10.9     42  13  14   0   4   9   6   3   3   2   0   3   1   0   0   0   0   0   0

 FEB    13.6     27  14  13   0   6   6  11   6   4   5   1   4   3   0   1   0   1   0   0

 MAR    13.6     28  11  14   0   3  14   8   4   5   6   1   3   2   0   0   0   0   0   0

 APR    15.1     21   6  17   0   9   8   8   4   3   8   4   6   4   0   1   0   0   0   0

 MAY    14.4     20  11  17   0   7   9   9   4   4  10   1   5   1   0   1   0   1   0   0

 JUN    14.2     23  11  15   0   6  12   9   5   2   8   3   4   3   0   0   0   0   0   0

 JUL    11.8     30  18  12   0   7  13   6   1   4   6   1   2   0   0   0   0   0   0   0

 AUG    12.5     29  11  15   0   3  13   9   6   3   7   1   2   1   0   0   0   0   0   0

 SEP    12.5     25  12  19   0   5  14  10   3   2   7   1   0   2   0   0   0   0   0   0

 OCT    12.5     24  13  17   0   6  14  10   3   2   6   2   2   0   0   0   0   0   0   0

 NOV    11.6     35  12  15   0   4  11   7   5   0   5   0   2   1   0   0   0   0   0   0

 DEC    12.7     29  14  17   0   5  12   7   1   0   6   1   1   6   0   0   0   1   0   0

---------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979   12.9     28  12  15   0   5  11   8   4   3   6   1   3   2   0   1   0   0   1   0
```

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                MINIMUM WIND YEAR

SITE LOCATION: CIRCLE              NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                       PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN    10.9     42  13  14   0   4   9   6   3   3   2   0   3   1   0   0   0   0   0   0

 FEB    13.6     27  14  13   0   6   6  11   6   4   5   1   4   3   0   1   0   1   0   0

 MAR    13.6     28  11  14   0   3  14   8   4   5   6   1   3   2   0   0   0   0   0   0

 APR    15.1     21   6  17   0   9   8   8   4   3   8   4   6   4   0   1   0   0   0   0

 MAY    14.4     20  11  17   0   7   9   9   4   4  10   1   5   1   0   1   0   1   0   0

 JUN    14.2     23  11  15   0   6  12   9   5   2   8   3   4   3   0   0   0   0   0   0

 JUL    11.8     30  18  12   0   7  13   6   1   4   6   1   2   0   0   0   0   0   0   0

 AUG    12.5     29  11  15   0   3  13   9   6   3   7   1   2   1   0   0   0   0   0   0

 SEP    12.5     25  12  19   0   5  14  10   3   2   7   1   0   2   0   0   0   0   0   0

 OCT    12.5     24  13  17   0   6  14  10   3   2   6   2   2   0   0   0   0   0   0   0

 NOV    11.6     35  12  15   0   4  11   7   5   0   5   0   2   1   0   0   0   0   0   0

 DEC    12.7     29  14  17   0   5  12   7   1   0   6   1   1   6   0   0   0   1   0   0

-------------------------------------------------------------------------------------------
 YEARLY AVERAGE:
  1979  12.9     28  12  15   0   5  11   8   4   3   6   1   3   2   0   1   0   0   1   0
```

```
              MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                    MAXIMUM WIND YEAR

SITE LOCATION: CIRCLE              NCC WEATHER STATION LOCATION: MILES CITY
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/76
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.33
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                         PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN    14.4     23  12  15   0   7  10   7   4   4   8   1   3   5   0   1   0   1   0   0

 FEB    15.4     16  11  13   0   4  14  15   4   4   6   3   4   3   0   1   1   1   1   0

 MAR    16.1     19   9  12   0   5  12   8   6   4   7   2   4   4   0   2   1   2   1   1

 APR    16.3     15   8   9   0   6   9  15   9   5  10   1   6   2   0   3   0   1   0   0

 MAY    14.4     21   9  12   0   9  11  15   5   3   6   1   1   5   0   1   0   1   0   1

 JUN    16.0     16   5   9   0   8  11  16   9   3  13   2   4   3   0   0   1   0   0   0

 JUL    14.1     14  12  16   0   9  11  14   6   3   8   0   3   0   0   1   0   0   0   1

 AUG    14.7     18  10  12   0   9  13  12   5   3   7   2   2   3   0   1   1   1   0   0

 SEP    12.3     26  15  17   0   9  10   7   1   2   5   2   2   1   0   0   0   0   0   0

 OCT    12.9     28  15  14   0  10   8  11   2   2   6   0   1   1   0   2   0   0   0   0

 NOV    12.1     33  15  17   0   5   7   7   4   2   4   0   0   3   0   0   0   0   0   0

 DEC    13.9     25  15  14   0   4   8  11   3   2   9   2   3   2   0   1   0   0   0   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1976   14.4     21  11  13   0   7  10  11   5   3   8   1   3   3   0   1   0   1   0   0
```

# APPENDIX I

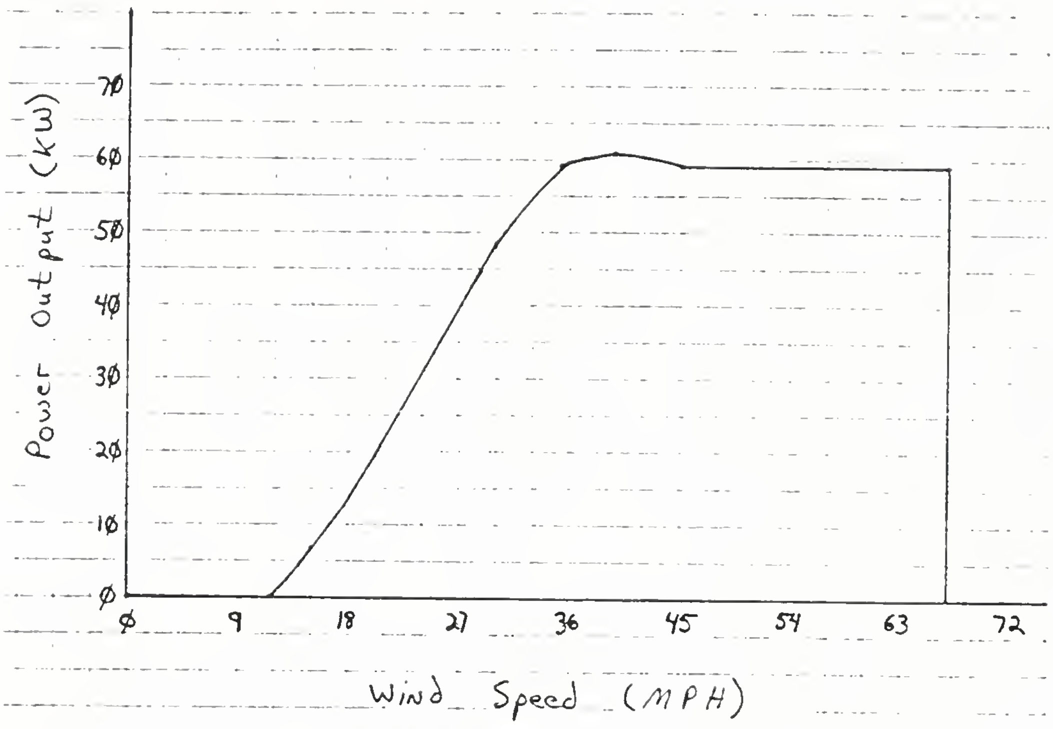
## Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon; Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

## APPENDIX II

Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
Wind Speed Versus Generator KWh Output



# APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   b) the total amount of your proposed investment.
      i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
      ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
      iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   c) Complete warranty information.
   d) Complete information for utility/home electric interface connection.
   e) Maintenance schedules and their costs.
   f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

Then, here, in general, are the steps to getting those first kilowatts flowing:

1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

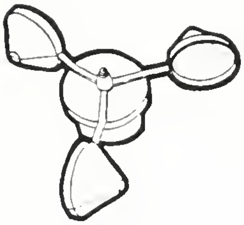
4 ) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.

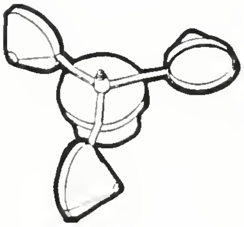
5 ) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.

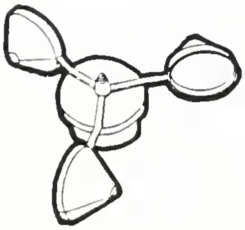
6 ) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.

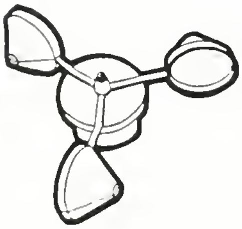
7 ) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The Dave Hastings Place, Conrad, MT

December 15, 1980 - March 6, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

# ACKNOWLEDGEMENTS

Gunderson Consulting Service is grateful to all those people who assisted in preparing this report.

We commend the Montana Legislature for allocating funds from the coal severance tax income to further the research, development and demonstration of all renewable energy resources. The staff at the Department of Natural Resources and Conservation including Jim Iverson, Mike Chapman, Georgia Brensdal, Jeannie Thurston, Dave Dysinger, Greg Mills and John Orndorff were of particular help. Special thanks to the Renewable Alternative Energy Advisory Council for awarding money for this unsolicited grant proposal.

The site owners who diligently charged and changed the systems' batteries, gathered the data and mailed it to the Department of Resources for storage are specially acknowledged. They are: Jim Salmond, Marcel Solum, Chuck and Karen Davis, Dave Hastings, Jerry McGillivray, Helen and Gordon Waller, Dan Heckford, Randy Moy, Pat and Ken Torgerson, Witt Hibbard and the Sieben Livestock Company, David Erickson and Ken Morrow.

The people at Gunderson Consulting who contributed to this project over the past year and a half are: Marylore Lahey for her work on the final report format, strip chart digitizing and general management of the project; Seana Young for her three months of computer programming; Al Gunderson for his five months of computer programming; Ken Walters for his work digitizing strip charts; Abby and Egypt for inspiration when it was needed most; and Dana Gunderson for his technical design, computer programming and general project management.

Both Charless Fowlkes and John Obermeier contributed expert advice which greatly added to the quality and accuracy of the material in this report.

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #DSR-2 at the Dave Hastings place near Conrad, Montana from December 15, 1980 to March 8, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensors used in the system which gathered this data. The system includes: a model A11-132 dual strip chart recorder housed inside a model A95-003 plastic case; a model A75-104 4-pole cup anemometer; a model A75-301 wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensors to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes .

The operational specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operational specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH
Temperature range -60 to 200 degrees F.

The operational specifications for the model A11-132 strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The strip chart recorder records a wind speed and direction reading every two seconds by making a mark on the pressure sensitive strip chart paper as it crosses a metal plate. To make the mark, an impact bar strikes the top side of the meter needles, one for wind speed and one for wind direction, which then touch the sensitive paper.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On December 15, 1980, under contract with DNRC, Gunderson Consulting installed wind monitoring system #DSR-2 at the Dave Hastings farm southeast of Conrad, Montana (Mailing address: Star Route Box 48, Conrad, Montana 59422.) Dave charged the batteries and changed the rolls of strip chart paper as they were filled. He mailed the filled strip charts to Gunderson Consulting who reviewed them for signs of equipment malfunction, then delivered them to the Renewable Energy Bureau of DNRC. In June 1982 the Department contracted with Gunderson Consulting to analyze and summarize the data.

To locate the monitoring site, travel 13 miles east from Conrad on State Route 218 to Minute Man missile marker R-29; turn south (right) and travel three miles to a crossroad and another one-half to three-fourths mile beyond the crossroad to an east (left) turn; turn east and continue one-fourth mile to the farm at the end of the road.

## Equipment History

The monitoring system (DSR-#2) operated properly at the site from 12/15/80 to 3/8/81 and produced the data which is contained in this study. After 3/8/81, the site owner detected a malfunction and, on 3/24/81, shipped the recorder back to DNRC for repair. On that date, Gunderson Consulting picked up the recorder from DNRC and shipped it to the manufacturer.

The manufacturer repaired the recorder and shipped it back to DNRC. Gunderson Consulting re-installed it at the Hastings farm on 6/21/81, where it apparently operated until Gunderson returned on 10/20/81 to remove it. At that time, the recorder was out of paper and was not operating. The site owner was not present, but his son said that the filled strip charts had been mailed to DNRC, according to instructions.

In June, 1982, DNRC delivered to Gunderson Consulting only the strip charts dating from the period 12/15/80 to 3/8/81. The whereabouts of the strip charts from the period 6/21/81 to 10/20/81 are unknown.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computed calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

The weekly and monthly wind direction summaries were prepared manually from the marks made by the wind direction needle on the eight direction tracks on strip chart. (One track on the strip chart is assigned to each octant of the compass--N, NE, E, SE, etc.). For each summary period, the operator counted the number of quarter-inch (15-minute) marks in each direction track on the strip chart at the same time he digitized the wind speed curve. He then divided the total number of marks in each direction track by the total number of marks in all direction tracks during the same period to derive the percentage of time the wind blew in each octant for the summary period.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Great Falls) is at 6.7 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station at Gore Hill in Great Falls. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three- hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most

useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P= (1/2)pKV^3$$

where P = wind power density
p = air density
V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density p is defined as: $p = A/(RT)$

where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P= \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## Data Use

First, refer to Appendix I and compare the average wind power density at your monitored site to the densities at other sites in the state. (Comparison of wind power densities provides the best picture of how one site's potential compares with others.)

Next, estimate the power output you might expect from a particular wind generator installed at your site. You will need the generator manufacturer's wind-speed-versus-power output graph, or "power characteristic curve' as it is sometimes called (Appendix II is such a curve for a Holec Windmatic model 14S wind generator), and the "Average Monthly and Yearly Wind Speed and Percentage Speed Profile" of your site. Follow the procedure in the example below to estimate yearly (or monthly) generator ouput. Then, to calculate a dollar value of the power that generator might generate under the conditions at your site, multiply the estimated generator output by the value of the electricity you would be displacing.

In the following example use the Power Characteristic Curve in Appendix II and the following annual wind speed percentage spectrum:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these annual percentage figures into the number of hours per year the wind blew in each bracket. Multiply the percent value from the percentage spectrum by the number of hours in a year. (365 X 24 = 8,760 hours in a year). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds in the less-than-10-MPH bracket. For the second bracket, the wind blew .05 X 8,760 = 438 hours at speeds between 10 and 10.99 MPH. This process can be continued for each bracket of the spectrum. The final result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 ... | <34 ... |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 ... | 0 ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

The next step is to assign a MPH value to the middle of each velocity bracket and then use the Power Characteristic Curve to find the generator's power output for each associated midpoint speed. The midpoint of each velocity bracket has been rounded to the nearest MPH for convenience below.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KW) FROM POWER CHARACTERISTIC CURVE

To do the final step, multiply the number of hours in each bracket by the generator output and add all of the ouputs together to obtain the total generator output for the period, which, in this example, is one year.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 | ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

In this example, the generator output for the total period (one year) is 51,771 KWh. To find the value of the electricity which would theoretically be displaced by this generator at a site with this wind speed profile, multiply the value of the electricity by the total production. In this example we will use $.0625/KWh for the unit value of displaced electricity; therefore, the total value of the displaced electricity would be $3,235.69 per year.

However, many factors other than the cost of the generator and the value of displaced electricity must be considered to make a realistic evaluation of the economics of wind electric generation at your site--factors such as: the one-time costs of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for the foundation, freight charges, fees for inspection and system checkout, and the continuous expenses of insurance, operation and maintenance. The following breakdown gives a broad guideline for the cost of a larges scale wind development:

Generator and Blade Assembly - 57%
Tower and Site Access - 11%
Foundation/Site Preparation - 9%
Operations/Maintenance - 9%
Assembly/Checkout - 8%
Other - 4%
Equipment Transportation - 2%

Source: from publication SERI/SP-732-728 pulbiished by the Solar Energy Research Institute, October 1980.

Not all of these costs will apply in the same percentages to every installation, but the likelihood is always a good that other costs will occur in their place.

As a rule of thumb, a wind site that has a wind power density of over 200 watts per square meter and has a minimum average wind speed of 12 MPH for at least six months per year should considered for wind development. The final decision to develop your wind potential is an investment decision which deserves the same degree of careful analysis as you give any other development investment. Appendix III is a suggested wind electric generation development guide.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

The multi-page summary titled "Wind Speed Summary (in MPH) and Percentage Spectrum" contains daily, weekly and monthly average wind speeds and a wind speed percentage spectrum for each speed average. This summary should be interpreted in the same manner as the preceeding summary.

On the summary sheet titled, "Weekly and Monthly Average Wind Power Density," the last column gives the weekly and monthly average wind power density at the site during the monitoring period. The average wind speed in mph is also shown.

The summary sheet titled, "Weekly & Monthly Wind Direction Profile," gives the approximate percent of time the wind was blowing in each of the 8 different compass directions during the monitoring period. (Please note that these directions are based on magnetic North, not geographic North.)

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors" for each time period, which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these

sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But while the preceeding summaries estimate wind power density, these estimate wind speed averages--the mean, minimum and maximum monthly and yearly average wind speeds likely to occur at the site--and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: CONRAD TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 12/15/80

| WEEK | WKLY AVG SPD | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MPH / DAY | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
| 12/20 | *12.2 | 51 | 10 | 6 | 5 | 5 | 12 | 2 | 3 | 1 | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/27 | 11.1 | 49 | 8 | 6 | 11 | 4 | 8 | 4 | 4 | 4 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| DEC | 10.9 | 54 | 8 | 7 | 7 | 4 | 9 | 3 | 3 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/ 3 | 7.5 | 78 | 3 | 7 | 4 | 2 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/10 | 6.8 | 88 | 1 | 2 | 2 | 1 | 3 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/17 | 6.4 | 87 | 5 | 4 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/24 | 7.8 | 80 | 3 | 3 | 1 | 1 | 4 | 1 | 2 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/31 | 5.3 | 95 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JAN | 6.5 | 83 | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/ 7 | 8.1 | 74 | 4 | 4 | 3 | 1 | 7 | 4 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/14 | 9.6 | 54 | 7 | 7 | 8 | 8 | 4 | 7 | 4 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/21 | 14.1 | 39 | 7 | 5 | 5 | 2 | 8 | 4 | 5 | 5 | 7 | 4 | 4 | 3 | 2 | 1 | 0 | 0 | 0 |
| 2/24 | * 8.3 | 81 | 7 | 4 | 1 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/28 | 5.7 | 90 | 4 | 1 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 9.6 | 63 | 6 | 5 | 5 | 3 | 5 | 4 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 3/ 7 | 6.8 | 81 | 0 | 3 | 2 | 4 | 2 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/ 8 | * 4.3 | 88 | 6 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 6.4 | 82 | 1 | 3 | 3 | 3 | 2 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

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              WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  CONRAD                     TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:  12/15/80

                                              PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
------------------------------------------------------------------------------------------------
  15      *23.4  7 HRS    0   0   0   0   0   0   0  29   0  29  14  29   0   0   0   0   0   0
  16       12.9          33  17   0   0   8  13   8   8   4   8   0   0   0   0   0   0   0   0
  17       11.4          29   4  21  17  13  13   4   0   0   0   0   0   0   0   0   0   0   0
  18       11.9          33  13   4   8   4  38   0   0   0   0   0   0   0   0   0   0   0   0
  19        8.2          75  21   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  20        5.7         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 12.2         51  10   6   5   5  12   2   3   1   3   1   2   0   0   0   0   0   0

  21        6.9         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  22        8.8          58  13   4   8   4  13   0   0   0   0   0   0   0   0   0   0   0   0
  23       11.0          29  13  13  25   8  13   0   0   0   0   0   0   0   0   0   0   0   0
  24        9.2          46  17  17  13   8   0   0   0   0   0   0   0   0   0   0   0   0   0
  25        9.7          63  13   4  13   0   4   0   0   4   0   0   0   0   0   0   0   0   0
  26       12.5          46   0   0  13   4  13   8   8   4   4   0   0   0   0   0   0   0   0
  27       19.3           0   4   4   4   0  13  17  17  17   8   4   4   4   0   4   0   0   0

WKLY  AVG=> 11.1         49   8   6  11   4   8   4   4   4   2   1   1   1   0   1   0   0   0

  28       10.0          54   4  21   4   4   8   4   0   0   0   0   0   0   0   0   0   0   0
  29       10.0          50   4  13  13   4  13   4   0   0   0   0   0   0   0   0   0   0   0
  30        8.2          83   4   4   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0
  31        7.1          83   0   0   4   4   8   0   0   0   0   0   0   0   0   0   0   0   0
------------------------------------------------------------------------------------------------
 DEC       10.9          54   8   7   7   4   9   3   3   2   2   1   1   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
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STARTING TIME:  0000 HOURS
STARTING DATE:   1/ 1/81

                                         PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
---------------------------------------------------------------------------------------------
    1       4.9         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    2       5.8          92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    3       6.7          83   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=> 7.5           78   3   7   4   2   5   1   0   0   0   0   0   0   0   0   0   0   0

    4       5.6         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    5       7.7          83   4   0   0   0   8   4   0   0   0   0   0   0   0   0   0   0   0
    6       8.4          79   0   4   4   0   0   0   4   0   8   0   0   0   0   0   0   0   0
    7       5.9         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    8       6.3          88   0   0   0   4   4   0   4   0   0   0   0   0   0   0   0   0   0
    9       7.1          63   0   8  13   4   8   4   0   0   0   0   0   0   0   0   0   0   0
   10       6.4         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=> 6.8           88   1   2   2   1   3   1   1   0   1   0   0   0   0   0   0   0   0

   11       5.5          96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   12       8.5          75   8   8   0   4   4   0   0   0   0   0   0   0   0   0   0   0   0
   13       4.2         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   14       5.9          96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   15       7.2          79   8  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   16       5.9          92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   17       7.4          71   4   0   8   4   8   4   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=> 6.4           87   5   4   1   1   2   1   0   0   0   0   0   0   0   0   0   0   0

   18     * 6.2 19 HRS   95   5   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   19       5.7          92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   20       4.4         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   21       7.4          79   8   4   0   0   8   0   0   0   0   0   0   0   0   0   0   0   0
   22       8.2          79   0   8   4   4   4   0   0   0   0   0   0   0   0   0   0   0   0
   23       6.9         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   24      15.9          21   4   4   0   0  13   8  13  25   8   4   0   0   0   0   0   0   0

WKLY AVG=> 7.8           80   3   3   1   1   4   1   2   4   1   1   0   0   0   0   0   0   0

   25       6.9          96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   26       3.4         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   27       3.5         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   28       5.4         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   29       3.6         100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   30       6.1          92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   31       8.0          75   4   4   0   0   4   4   4   4   0   0   0   0   0   0   0   0   0

WKLY AVG=> 5.3           95   2   1   0   0   1   1   1   1   0   0   0   0   0   0   0   0   0

---------------------------------------------------------------------------------------------
  JAN       6.5          88   3   3   1   1   2   1   1   1   1   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  3
STARTING TIME:  0000 HOURS
STARTING DATE:   2/ 1/81

                                             PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10  <11  <12  <13  <14  <16  <18  <20  <22  <24  <26  <28  <30  <32  <34  <36  <38  >38
----------------------------------------------------------------------------------------------------------------
   1         7.0         88    0    0    0    0    0    8    4    0    0    0    0    0    0    0    0    0    0
   2         5.7        100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   3         6.4         92    4    4    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
   4         9.4         54    4    8    8    0   17    4    4    0    0    0    0    0    0    0    0    0    0
   5         6.2         92    0    0    0    0    8    0    0    0    0    0    0    0    0    0    0    0    0
   6        13.6         29    8    4    8    0   17   17    0   17    0    0    0    0    0    0    0    0    0
   7         8.5         67    8    8    4    4    4    0    0    4    0    0    0    0    0    0    0    0    0

WKLY  AVG=>  8.1         74    4    4    3    1    7    4    1    3    0    0    0    0    0    0    0    0    0

   8         9.5         58    0    0    0   17    8   13    4    0    0    0    0    0    0    0    0    0    0
   9        10.6         54    0    8    4   13    0   13    8    0    0    0    0    0    0    0    0    0    0
  10        10.4         46   17    8   13    4    0    4    0    4    0    4    0    0    0    0    0    0    0
  11         8.0         75    4    0    0    0    4    8    8    0    0    0    0    0    0    0    0    0    0
  12         5.9         83    4    4    4    4    0    0    0    0    0    0    0    0    0    0    0    0    0
  13        10.4         42    4   13   13   17    8    4    0    0    0    0    0    0    0    0    0    0    0
  14        12.2         17   21   17   21    0    8    8    8    0    0    0    0    0    0    0    0    0    0

WKLY  AVG=>  9.6         54    7    7    8    8    4    7    4    1    0    1    0    0    0    0    0    0    0

  15         9.4         54   13    8    8    4    4    8    0    0    0    0    0    0    0    0    0    0    0
  16        12.7         42    8    4    8    0   13    4    4    4    4    0    4    4    0    0    0    0    0
  17        13.5         46    8    0    4    0    4    8    0    4    8    4    0    8    4    0    0    0    0
  18        16.1         21   13    4    4    8   13    0    8    4    8    0    8    4    4    0    0    0    0
  19        15.1         50    4    4    4    0    0    0    4    0    4    4    8    4    4    8    0    0    0
  20        16.8         33    4    8    0    0    4    0    8    4   13   17    4    0    4    0    0    0    0
  21        15.1         29    0    4    4    0   21    4   13   17    8    0    0    0    0    0    0    0    0

WKLY  AVG=> 14.1         39    7    5    5    2    8    4    5    5    7    4    4    3    2    1    0    0    0

  22         8.1         75    4    4    4    4    4    0    4    0    0    0    0    0    0    0    0    0    0
  23         8.0         88    0    8    0    0    4    0    0    0    0    0    0    0    0    0    0    0    0
  24       * 8.7 20 HRS  80   20    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  25         NO DATA
  25       * 6.3 10 HRS  90   10    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  26         8.3         71    8    4   13    0    4    0    0    0    0    0    0    0    0    0    0    0    0
  27         4.6        100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
  28         3.6        100    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0

WKLY  AVG=>  6.8         86    5    3    3    1    2    0    1    0    0    0    0    0    0    0    0    0    0

----------------------------------------------------------------------------------------------------------------
  FEB        9.6         63    6    5    5    3    5    4    3    2    2    1    1    1    1    0    0    0    0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  4
STARTING TIME:  0000 HOURS
STARTING DATE:   3/ 1/81

                                                 PERCENTAGE WIND SPEED PROFILE
 DATE    AVG WIND SPD <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
---------------------------------------------------------------------------------------------
   1        5.5        92   0   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   2        8.6        75   0   8   0   0   0   8   8   0   0   0   0   0   0   0   0   0   0
   3        4.6       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   4        4.2       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   5        9.9        50   0   0  13   0   8  29   0   0   0   0   0   0   0   0   0   0   0
   6        9.3        50   0   8   0  25   8   8   0   0   0   0   0   0   0   0   0   0   0
   7        5.3       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  6.8       81   0   3   2   4   2   7   1   0   0   0   0   0   0   0   0   0   0

   8     * 4.3 16 HRS  88   6   0   6   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   9      NO DATA
  10      NO DATA
  11      NO DATA
  12      NO DATA
  13      NO DATA
  14      NO DATA

WKLY  AVG=>  4.3       88   6   0   6   0   0   0   0   0   0   0   0   0   0   0   0   0   0

---------------------------------------------------------------------------------------------
 MAR        6.4        82   1   3   3   3   2   6   1   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

# WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: CONRAD
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 12/15/80

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 12/20 | *12.2 | | | 114 |
| 12/27 | 11.1 | | | 126 |
| DEC | 10.9 | 891.9 | 23.8 | 104 |
| 1/ 3 | 7.5 | | | 38 |
| 1/10 | 6.8 | | | 35 |
| 1/17 | 6.4 | | | 23 |
| 1/24 | 7.8 | | | 61 |
| 1/31 | 5.3 | | | 17 |
| JAN | 6.5 | 891.9 | 33.8 | 32 |
| 2/ 7 | 8.1 | | | 58 |
| 2/14 | 9.6 | | | 81 |
| 2/21 | 14.1 | | | 281 |
| 2/24 | * 8.3 | | | 38 |
| 2/28 | 5.7 | | | 17 |
| FEB | 9.6 | 889.2 | 30.8 | 114 |
| 3/ 7 | 6.8 | | | 40 |
| 3/ 8 | * 4.3 | | | 13 |
| MAR | 6.4 | 887.8 | 37.2 | 38 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# WEEKLY & MONTHLY WIND DIRECTION PROFILE

Note: The wind direction values read from the strip charts were interpreted as specified by the manufacturer, i.e., .25 inch of strip chart length representing 15 minutes of direction data. No attempt was made to correct wind direction data to account for recorder motor speed variations as ambient temperature varied. The greatest speed variation we noted amounted to + or - 17.15%. However, a correction was made in the wind speed data. Thus the distribution of the wind direction data in the table below does not correspond to the distribution of wind speed over the same period of time.

LOCATION: CONRAD
STARTING TIME: 1700
STARTING DATE: 12/20/80

| WEEK | -PERCENTAGE PROFILE OF WIND DIRECTION- | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ENDING | N | NW | W | SW | S | SE | E | NE |
| 12/20 * | 0 | 30 | 21 | 27 | 21 | 0 | 0 | 0 |
| 12/27 | 0 | 32 | 44 | 14 | 10 | 0 | 0 | 0 |
| DEC | 0 | 31 | 34 | 20 | 15 | 0 | 0 | 0 |
| 1/3/81 | 0 | 47 | 35 | 13 | 6 | 0 | 0 | 0 |
| 1/10 | 0 | 40 | 30 | 13 | 17 | 0 | 0 | 0 |
| 1/17 * | 0 | 41 | 29 | 23 | 8 | 0 | 0 | 0 |
| 1/24 * | 0 | 41 | 46 | 11 | 1 | 0 | 0 | 0 |
| 1/31 | 0 | 49 | 19 | 20 | 12 | 0 | 0 | 0 |
| JAN | 0 | 44 | 32 | 15 | 9 | 0 | 0 | 0 |
| 2/7 | 0 | 50 | 28 | 10 | 11 | 0 | 0 | 0 |
| 2/14 | 0 | 22 | 43 | 30 | 6 | 0 | 0 | 0 |
| 2/21 * | 0 | 40 | 38 | 13 | 8 | 0 | 0 | 0 |
| 2/28 * | 0 | 62 | 15 | 18 | 6 | 0 | 0 | 0 |
| FEB | 0 | 41 | 32 | 19 | 8 | 0 | 0 | 0 |
| 3/7 * | 0 | 50 | 25 | 12 | 12 | 0 | 0 | 0 |
| MAR | 0 | 50 | 25 | 12 | 12 | 0 | 0 | 0 |
| PERIOD TOT: | 0 | 41 | 32 | 17 | 10 | 0 | 0 | 0 |

* this week contains less than 7 days of direction data;
the direction sensor was aligned with the magnetic north pole

MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: CONRAD
DNRC TOWER HEIGHT: 10.0 METERS
NCC TOWER HEIGHT: 6.7 METERS
STARTING TIME: 1600 HOURS
STARTING DATE: 12/15/80

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION FACTORS-> | | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 12/20 | *0.85 | 0.48 | 1.05 | 0 | 17 | 50 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/27 | 0.98 | 0.58 | 1.59 | 0 | 14 | 43 | 14 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| DEC | 0.86 | 0.37 | 1.59 | 0 | 29 | 35 | 24 | 6 | 6 | 0 | 0 | 0 | 0 | 0 |
| 1/ 3 | 0.61 | 0.35 | 1.11 | 0 | 57 | 29 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/10 | 0.62 | 0.36 | 0.76 | 0 | 43 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/17 | 0.63 | 0.43 | 1.03 | 0 | 57 | 29 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/24 | 0.57 | 0.35 | 1.20 | 0 | 86 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1/31 | 0.73 | 0.31 | 1.19 | 0 | 29 | 43 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JAN | 0.63 | 0.31 | 1.20 | 0 | 52 | 35 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/ 7 | 0.72 | 0.57 | 0.95 | 0 | 14 | 71 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/14 | 0.61 | 0.42 | 0.92 | 0 | 71 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/21 | 0.60 | 0.37 | 0.73 | 0 | 29 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/24 | *0.66 | 0.41 | 1.07 | 0 | 67 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/28 | 0.74 | 0.52 | 1.08 | 0 | 25 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FEB | 0.66 | 0.37 | 1.08 | 0 | 39 | 46 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/ 7 | 0.79 | 0.34 | 1.34 | 0 | 29 | 43 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/ 8 | *0.87 | 0.87 | 0.87 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| MAR | 0.80 | 0.34 | 1.34 | 0 | 25 | 50 | 13 | 13 | 0 | 0 | 0 | 0 | 0 | 0 |
| STUDY PERIOD | 0.70 | 0.31 | 1.59 | 0 | 40 | 40 | 15 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

```
        MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                  MEAN WIND YEAR


SITE LOCATION: CONRAD                NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE         AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                  (F)                    (W/M2)
-----------------------------------------------------------------------------------------
 JAN        12.6              887.7                 24.9                     177

 FEB        10.1              887.3                 29.6                      82

 MAR        10.7              884.5                 39.5                      92

 APR        10.3              886.9                 40.2                     101

 MAY         9.5              886.3                 59.4                      74

 JUN        10.0              887.5                 63.6                      87

 JUL         8.1              889.5                 71.4                      48

 AUG         8.2              889.0                 71.2                      47

 SEP         8.7              890.0                 58.2                      56

 OCT        10.8              889.5                 49.2                     112

 NOV        10.0              888.7                 25.2                     107

 DEC        11.3              887.2                 28.9                     150

-----------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973       10.0                                                              94
```

## MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
## MINIMUM WIND YEAR

SITE LOCATION: CONRAD NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

| MONTH | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (F) | AVG WIND POWER DENSITY (W/M2) |
|---|---|---|---|---|
| JAN | 9.2 | 887.7 | 6.5 | 100 |
| FEB | 10.0 | 887.1 | 18.8 | 114 |
| MAR | 9.6 | 884.5 | 34.7 | 92 |
| APR | 9.2 | 886.8 | 40.7 | 67 |
| MAY | 7.5 | 886.4 | 51.5 | 44 |
| JUN | 8.0 | 887.4 | 62.9 | 50 |
| JUL | 6.6 | 889.5 | 69.0 | 27 |
| AUG | 7.0 | 889.2 | 68.5 | 30 |
| SEP | 7.2 | 890.2 | 62.9 | 33 |
| OCT | 7.5 | 889.3 | 49.4 | 43 |
| NOV | 8.5 | 888.6 | 33.4 | 49 |
| DEC | 12.4 | 886.6 | 34.6 | 176 |
| YEARLY AVERAGE:<br>1979 | 8.5 | | | 67 |

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                               MAXIMUM WIND YEAR

SITE LOCATION: CONRAD             NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE         AVG TEMPERATURE      AVG WIND POWER DENSITY
           (MPH)              (MBS)                  (F)                   (W/M2)
-------------------------------------------------------------------------------------------
 JAN       13.7               883.8                 19.8                   270

 FEB       14.0               885.2                 33.8                   192

 MAR       12.1               882.2                 33.3                   185

 APR        9.3               886.2                 47.1                    67

 MAY        9.8               885.5                 49.5                    86

 JUN        9.1               886.2                 66.9                    60

 JUL        8.1               888.9                 72.9                    50

 AUG        7.2               890.6                 62.9                    27

 SEP        7.5               892.3                 54.8                    45

 OCT        9.3               891.6                 51.4                    77

 NOV       10.8               888.3                 38.7                   113

 DEC       13.8               885.5                 32.5                   217

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974      10.4                                                            114
```

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                   MEAN WIND YEAR

SITE LOCATION: CONRAD                NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                         PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
----------------------------------------------------------------------------------------------

 JAN    12.6     36   2   8   4   9  13   7   7   7   4   2   1   0   0   0   0   0   0   0

 FEB    10.1     53   6   9   5  11   9   2   4   2   0   0   0   0   0   0   0   0   0   0

 MAR    10.7     48   6   7   7  12   9   4   2   3   1   0   0   0   0   0   0   0   0   0

 APR    10.3     56   8   4   5  10   6   3   1   4   1   0   2   0   0   0   0   0   0   0

 MAY     9.5     59   8   6   4   8   5   3   2   3   1   0   0   0   0   0   0   0   0   0

 JUN    10.0     57   5   8   5   4   8   3   2   5   1   0   0   0   0   0   0   0   0   0

 JUL     8.1     77   3   4   4   5   2   2   0   1   0   1   0   0   0   0   0   0   0   0

 AUG     8.2     75   6   4   4   3   3   1   1   2   0   0   0   0   0   0   0   0   0   0

 SEP     8.7     69   5   4   5   5   5   3   2   2   0   0   0   0   0   0   0   0   0   0

 OCT    10.8     48   7   6   9   7   6   6   3   6   1   1   0   0   0   0   0   0   0   0

 NOV    10.0     56   7   3   4   6   6   8   3   4   1   0   1   0   0   0   0   0   0   0

 DEC    11.3     45   5   4   5   7   9   8   4   7   3   1   0   1   0   0   0   0   0   0

 ---------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973   10.0     57   6   5   5   7   7   4   2   4   1   1   0   0   0   0   0   0   0   0
```

```
            MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                  MINIMUM WIND YEAR


SITE LOCATION: CONRAD              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                    PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN     9.2     52   7   4   3   9   9   5   5   5   1   0   0   0   0   0   0   0   0   0

 FEB    10.0     54   4   4   5   6  10   6   3   5   1   1   0   0   0   0   0   0   0   0

 MAR     9.6     54   6   5   5   8   8   5   4   2   0   1   0   0   0   0   0   0   0   0

 APR     9.2     64   6   3   6   8   6   4   2   2   0   0   0   0   0   0   0   0   0   0

 MAY     7.5     82   5   1   1   4   3   2   1   0   0   0   0   0   0   0   0   0   0   0

 JUN     8.0     74   4   4   3   5   5   2   0   1   0   0   0   0   0   0   0   0   0   0

 JUL     6.6     87   3   3   3   3   1   1   0   0   0   0   0   0   0   0   0   0   0   0

 AUG     7.0     85   3   2   2   4   3   0   1   0   0   0   0   0   0   0   0   0   0   0

 SEP     7.2     82   4   3   2   4   2   1   1   0   0   0   0   0   0   0   0   0   0   0

 OCT     7.5     76   3   3   2   7   5   3   0   0   0   0   0   0   0   0   0   0   0   0

 NOV     8.5     67   7   8   4   7   5   2   0   0   0   0   0   0   0   0   0   0   0   0

 DEC    12.4     41   7   3   5   8   9   9   3   7   2   2   3   1   0   0   0   0   0   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979    8.5     68   5   3   3   6   5   3   2   2   0   0   0   0   0   0   0   0   0   0
```

```
            MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                  MAXIMUM WIND YEAR

SITE LOCATION: CONRAD               NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.70
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                          PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED     <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
------------------------------------------------------------------------------------------

 JAN    13.7      34   5   3   7   9   8   8   4  10   2   3   5   1   1   0   1   0   0   0

 FEB    14.0      23   6   5   7  10  15  13   6  10   2   2   1   0   0   0   0   0   0   0

 MAR    12.1      41   7   5   6  10   7   6   4   6   2   2   0   1   1   0   1   0   0   0

 APR     9.3      63   7   6   3   8   4   4   2   2   0   0   0   0   0   0   0   0   0   0

 MAY     9.8      54   8   6   5  11   5   3   2   5   1   0   0   0   0   0   0   0   0   0

 JUN     9.1      67   5   5   3   8   4   4   2   1   1   0   0   0   0   0   0   0   0   0

 JUL     8.1      72   6   3   5   5   3   2   1   3   0   0   0   0   0   0   0   0   0   0

 AUG     7.2      81   8   4   4   1   1   1   0   0   0   0   0   0   0   0   0   0   0   0

 SEP     7.5      78   5   3   3   3   4   2   2   1   0   0   0   0   0   0   0   0   0   0

 OCT     9.3      59   7   7   5   8   4   3   4   4   0   0   0   0   0   0   0   0   0   0

 NOV    10.8      47   6   4   8  10   9   7   3   6   1   0   0   0   0   0   0   0   0   0

 DEC    13.8      31   5   3   7  11  10   8   5   8   4   3   4   1   0   0   0   0   0   0

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974   10.4      54   6   4   5   8   6   5   3   5   1   1   1   0   0   0   0   0   0   0
```

# APPENDIX I

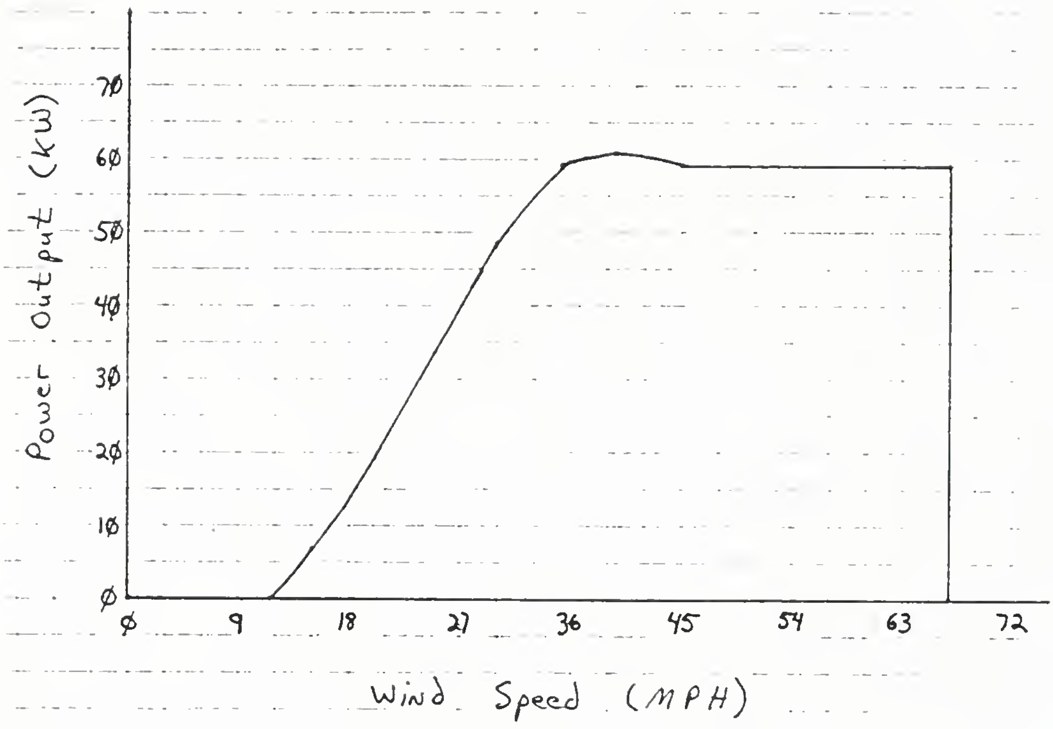
## Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon; Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

## APPENDIX II

Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
Wind Speed Versus Generator kWh Output



# APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   b) the total amount of your proposed investment.
      i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
      ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
      iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   c) Complete warranty information.
   d) Complete information for utiltiy/home electric interface connection.
   e) Maintenance schedules and their costs.
   f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

## III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

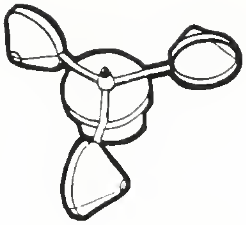
If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

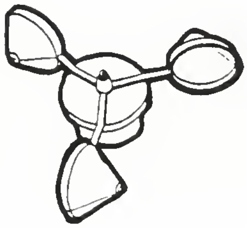
Then, here, in general, are the steps to getting those first kilowatts flowing:

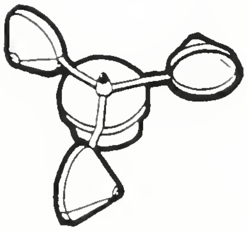
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

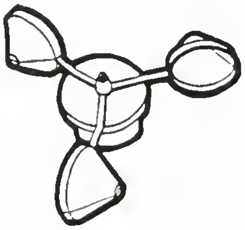
4 ) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.
5 ) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6 ) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7 ) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The Randy Moy Place, Helena, Mt.

November 3, 1980 - July 26, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

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# ACKNOWLEDGEMENTS

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We commend the Montana Legislature for allocating funds from the coal severence tax income to further the research, development and demonstration of all renewable energy resources and thank the Renewable Alternative Energy Advisory Council for awarding us this grant. We would like to mention the names of people on the staff of the Renewable Energy Bureau at DNRC who gave help and encouragement to this project--Jim Iverson, Mike Chapman, Georgia Brensdal, Jeannie Thurston, Dave Dysinger, Greg Mills and John Orndorff.

We also wish to acknowledge the contribution of the site owners, who diligently charged and changed the systems' batteries, gathered the data and forwarded it to DNRC for storage. They are: Jim Salmond, Marcel Solum, Chuck and Karen Davis, Dave Hastings, Jerry McGillivray, Helen and Gordon Waller, Dan Heckford, Randy Moy, Pat and Ken Torgerson, Witt Hibbard and the Sieben Livestock Company, David Erickson and Ken Morrow.

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Both Charless Fowlkes and John Obermeier contributed expert advice which greatly added to the quality and accuracy of the material in this report.

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #SSR-1 at the Randy Moy place near Helena, Montana from August 30, 1980 to October 18, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder used in the system which gathered this data. The system included a single-channel strip chart recorder housed in a plastic case, a 4-pole cup anemometer, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensor to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operating specifications for the anemometer are:
Wind velocity range: 3- 150 MPH
Temperature range -60 to 200 degrees F.

The operating specifications for the strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The the strip chart recorder records a wind speed reading every two seconds by making a mark on the strip chart. To make the mark, an impact bar strikes the top side of the meter needle, which then touches pressure-sensitive paper (a "strip chart") moving slowly beneath the needle. These dots accumulate on the moving paper forming a graph of the wind speed.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25′ radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On August 30, 1980, under contract with DNRC, Gunderson Consulting installed DNRC's wind monitoring system #SSR-1 at the Randy Moy residence northwest of Helena at 4258 Franklin Mine Road. Between the date of installation and October 18, 1981, Randy charged the batteries and changed the rolls of strip chart paper as they were filled.

In June 1982, DNRC contracted with Gunderson Consulting to analyze and summarize the data on the strip charts and prepare this report.

The monitoring site is located about two and one-half miles west of the Scratch Gravel Landfill on the Franklin Mine Road at the western edge of the city of Helena.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

No wind direction data was gathered because the single-channel recorder can only record data from only one sensor at a time.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Helena, MT) is at 6.10 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \frac{H}{h}^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station in Helena. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three-hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P= (1/2)pkV^{3}$$

where P = wind power density
p = air density

V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms
Note that air density p is defined as: p = A/(RT)
where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## How to Use This Data

First, refer to Appendix I to get an idea of how the average wind power density at your site compares with the density at other locations in Montana. A comparison of wind power densities gives the best perspective on the relative potential of several sites.

If you were encouraged by the comparison, you should follow the procedure below to calculate a hypothetical yearly power output of a particular wind generator if it were installed at your site. This procedure uses a wind generator's Power Characteristic Curve and a yearly average wind speed percentage profile. In our example, we use a hypothetical yearly average wind speed profile and the curve for a Windmatic 14S generator, given in Appendix II. In your calculations, you would use the actual yearly average wind speeds given in this report at the bottom of the chart titled, "Monthly & Yearly Avg Wind Spd (MPH) and Percentage Profile--Mean Wind Year", and either the Windmatic's curve from Appendix II or one you get for a different generator.

PERCENT OF WIND IN VELOCITY BRACKETS (hypothetical)

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these percentage figures into the number of hours per year the wind blew in each bracket. Multiply the value in the first percentage bracket (41%, = .41) by the number of hours in a year (365 X 24 = 8,760 hours). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds of 10 MPH or less. In the second bracket (10 to 10.99 MPH), the wind blew .05 X 8,760 = 438 hours. Apply this process to each bracket of the spectrum, and the result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

You will use the numbers of hours in Step 3.

The second step is to fit the Power Characteristic Curve beneath the midpoints given below. If you are using the Windmatic's curve, you can use the table below just as it is.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KWH) FROM POWER CHARACTERISTIC CURVE

The third step is to multiply the number of hours in each bracket (Step 1) by the corresponding generator output in each bracket (Step 2). These products are shown below the line:

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 | ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

and then add the outputs from all the brackets. This gives the hypothetical yearly generator output, which in this example is 51,771 KWh.

Now you are ready to estimate the yearly dollar value of the electricity that a particular generator would theoretically produce if it were installed at your site. Multiply the total generator output (51,771 KWh) by your local utility's current electric rate (honk if you love puns). In this example we use $.0625/KWh but you will have to get the actual residential rate from your local utility. $.0625 x 51,771 = $3,235.69 annual value, sometimes referred to as "displaced cost", of the electricity generated in this hypothetical case.

* * * * *

The value of the displaced electricity and the cost of the generator are two of the factors you have to consider if you want to make a realistic evaluation of the economics of wind electric generation. There are many others: cost of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for pouring the foundation and erecting the tower, inspection fees, system checkout, insurance, shipping, maintenance and always at least one more item that no one thought of. Below, from the Solar Energy Research Institute in Golden, Colorado, is a breakdown of the cost to be expected in a large scale wind development:

| | |
|---|---|
| Generator and Blade Assembly - | 57% |
| Tower and Site Access - | 11% |
| Foundation/Site Preparation - | 9% |
| Operations/Maintenance - | 9% |
| Assembly/Checkout - | 8% |
| Other - | 4% |
| Equipment Transportation - | 2% |

Source: publication SERI/SP-732-728, the Solar Energy Research Institute, October 1980.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors", which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But these estimate wind speed averages likely to occur at the site and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

# WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: HELENA
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 11/ 3/80

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
| 11/ 8 | *10.1 | 68 | 4 | 2 | 2 | 1 | 4 | 2 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 3 | 2 | 0 |
| 11/ 9 | *19.4 | 0 | 14 | 14 | 14 | 14 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 29 | 0 | 0 |
| 11/15 | 4.4 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/22 | 7.0 | 79 | 1 | 2 | 2 | 1 | 6 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/29 | 8.8 | 65 | 2 | 2 | 2 | 3 | 5 | 9 | 4 | 2 | 2 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| NOV | 9.0 | 69 | 3 | 2 | 3 | 2 | 5 | 5 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| 12/ 4 | * 6.3 | 77 | 7 | 2 | 6 | 2 | 3 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 12/ 6 | 10.4 | 40 | 10 | 0 | 0 | 20 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/13 | * 5.9 | 84 | 3 | 2 | 2 | 1 | 3 | 2 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| DEC | 5.9 | 83 | 4 | 2 | 2 | 2 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/11 | 8.4 | 61 | 9 | 13 | 7 | 7 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/18 | 9.1 | 70 | 5 | 7 | 6 | 2 | 1 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/25 | 8.8 | 64 | 6 | 6 | 4 | 5 | 10 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUL | 8.3 | 71 | 6 | 6 | 5 | 3 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 1 | 6.6 | 86 | 7 | 1 | 4 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 2 | * 5.3 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 5.6 | 89 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

```
            WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  HELENA                   TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:  11/ 3/80

                                              PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD   <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
------------------------------------------------------------------------------------------------
    3     * 6.9  7 HRS    86  14   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4       8.4           83   0   0   0   0   0   0   0   4   4   4   4   0   0   0   0   0   0
    5       3.8          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    6       9.0           58   4   8   0   4   8  13   0   0   4   0   0   0   0   0   0   0   0
    7       7.2           79  13   0   4   0   4   0   0   0   0   0   0   0   0   0   0   0   0
    8      25.1           13   0   0   4   0   8   0   4   8   4   0   8  13   8   4  17   8   0

WKLY AVG=> 10.1           68   4   2   2   1   4   2   1   2   2   1   2   2   2   1   3   2   0

    9     *19.4  7 HRS     0  14  14  14  14   0   0  14   0   0   0   0   0   0   0  29   0   0
   10       NO DATA
   11       NO DATA
   12       NO DATA
   13       NO DATA
   14       NO DATA
   15     * 4.4 10 HRS   100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=> 11.9           59   6   6   6   6   0   0   6   0   0   0   0   0   0   0  12   0   0

   16       4.7          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   17       3.6          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   18       9.3           67   4   0   0   0   4   4  17   4   0   0   0   0   0   0   0   0   0
   19       7.2           79   0   0   4   0   4  13   0   0   0   0   0   0   0   0   0   0   0
   20       8.4           58   0   8   8   0  13   8   0   4   0   0   0   0   0   0   0   0   0
   21       5.4           92   0   4   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0
   22      10.3           54   4   4   4   8  21   4   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  7.0           79   1   2   2   1   6   5   2   1   0   0   0   0   0   0   0   0   0

   23       3.9          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   24       8.3           63   0   8   4   0   8   8   4   4   0   0   0   0   0   0   0   0   0
   25       7.1           75   4   0   0   0   8  13   0   0   0   0   0   0   0   0   0   0   0
   26      15.3           17   4   8   4   8  13  21   0  13   8   4   0   0   0   0   0   0   0
   27       7.3           79   0   0   0   0   0  17   4   0   0   0   0   0   0   0   0   0   0
   28      12.6           42   8   0   8   8   8   0  17   0   0   4   0   0   4   0   0   0   0
   29       7.3           83   0   0   0   4   0   4   0   0   4   4   0   0   0   0   0   0   0

WKLY AVG=>  8.8           65   2   2   2   3   5   9   4   2   2   2   0   0   1   0   0   0   0

   30      11.8           46  13   0  17   4   8   0   0   0   0   4   4   4   0   0   0   0   0
------------------------------------------------------------------------------------------------
  NOV       9.0           69   3   2   3   2   5   5   2   2   1   1   1   1   1   0   1   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  0000 HOURS
STARTING DATE:  12/ 1/80

                                                 PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
----------------------------------------------------------------------------------------------
    1       8.9         63  17   4   8   4   4   0   0   0   0   0   0   0   0   0   0   0   0
    2       3.4        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    3       4.4         96   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4     * 2.7  2 HRS 100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    5       NO DATA
    6     *10.4 10 HRS  40  10   0   0  20  30   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  7.0         73   7   2   6   4   6   0   0   0   0   1   1   1   0   0   0   0   0

    7       2.6        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    8       7.9         67   0   0   8   4   4  13   0   0   0   0   0   4   0   0   0   0   0
    9       6.2         88   0   4   4   0   0   0   0   0   0   4   0   0   0   0   0   0   0
   10       6.5         83   0   0   0   4   8   0   4   0   0   0   0   0   0   0   0   0   0
   11       7.5         75   4   8   4   0   4   0   0   0   4   0   0   0   0   0   0   0   0
   12       7.0         79  17   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0
   13     * 3.1 18 HRS 100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   14       NO DATA

WKLY AVG=>  5.9         84   3   2   2   1   3   2   1   0   1   1   0   1   0   0   0   0   0

----------------------------------------------------------------------------------------------
  DEC       5.9         83   4   2   2   2   4   1   0   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  3
STARTING TIME:  2000 HOURS
STARTING DATE:   7/ 8/81

                                                      PERCENTAGE WIND SPEED PROFILE
  DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
------------------------------------------------------------------------------------------------
    8     * 6.2  4 HRS    75   0  25   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    9       8.0           71   4   8   0  13   0   4   0   0   0   0   0   0   0   0   0   0   0
   10      10.0           46  17  21   8   0   8   0   0   0   0   0   0   0   0   0   0   0   0
   11       9.4           63   8   8  13   8   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  8.4           61   9  13   7   7   3   1   0   0   0   0   0   0   0   0   0   0   0

   12       7.1           83  13   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   13       7.6           88   4   0   0   0   0   4   4   0   0   0   0   0   0   0   0   0   0
   14      12.7           33   0  13  13   0   4  17  17   4   0   0   0   0   0   0   0   0   0
   15       9.9           54   8  17   4   4   4   8   0   0   0   0   0   0   0   0   0   0   0
   16       8.9           75   0  13   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   17       9.1           75   8   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   18       8.8           83   4   0   4   4   0   0   0   4   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.1           70   5   7   6   2   1   4   3   1   0   0   0   0   0   0   0   0   0

   19       5.6          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   20       8.9           58   0   0   4   8  21   4   4   0   0   0   0   0   0   0   0   0   0
   21       7.4           79   8   0   0   0   8   4   0   0   0   0   0   0   0   0   0   0   0
   22       8.7           71   4   4   0  13   8   0   0   0   0   0   0   0   0   0   0   0   0
   23      12.1           33   8  17   0   0  17  21   4   0   0   0   0   0   0   0   0   0   0
   24       9.3           50  13   4  13   8  13   0   0   0   0   0   0   0   0   0   0   0   0
   25       9.7           58   8  17   8   4   0   4   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  8.8           64   6   6   4   5  10   5   1   0   0   0   0   0   0   0   0   0   0

   26       7.9           96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   27       9.6           54  25   4  13   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   28       4.9          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   29       5.4          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   30       6.5           83   4   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   31       5.9           83   4   0   4   4   4   0   0   0   0   0   0   0   0   0   0   0   0
------------------------------------------------------------------------------------------------
  JUL       8.3           71   6   6   5   3   4   3   1   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  4
STARTING TIME:  0000 HOURS
STARTING DATE:   8/ 1/81

                                                PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
    1        5.9          88   8   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0   0

WKLY AVG=>  6.6           86   7   1   4   1   1   0   0   1   0   0   0   0   0   0   0   0   0

    2      * 5.3  3 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    3       NO DATA
    4       NO DATA
    5       NO DATA
    6       NO DATA
    7       NO DATA
    8       NO DATA

WKLY AVG=>  5.3          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  AUG       5.6           89   7   0   0   0   0   0   0   4   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

# WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: HELENA TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 11/ 3/80

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 11/ 8 | *10.1 | | | 256 |
| 11/ 9 | *19.4 | | | 687 |
| 11/15 | 4.4 | | | 7 |
| 11/22 | 7.0 | | | 48 |
| 11/29 | 8.8 | | | 103 |
| NOV | 9.0 | 884.4 | 34.9 | 133 |
| 12/ 4 | * 6.3 | | | 58 |
| 12/ 6 | 10.4 | | | 88 |
| 12/13 | * 5.9 | | | 42 |
| DEC | 5.9 | 884.4 | 26.9 | 37 |
| 7/11 | 8.4 | | | 46 |
| 7/18 | 9.1 | | | 55 |
| 7/25 | 8.8 | | | 56 |
| JUL | 8.3 | 882.7 | 67.7 | 46 |
| 8/ 1 | 6.6 | | | 23 |
| 8/ 2 | * 5.3 | | | 7 |
| AUG | 5.6 | 883.4 | 69.5 | 24 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

## MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: HELENA NCC WEATHER STATION LOCATION: HELENA
DNRC TOWER HEIGHT: 10.0 METERS
NCC TOWER HEIGHT: 6.1 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 11/ 3/80

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION | FACTORS-> | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 11/ 8 | *1.21 | 0.78 | 1.80 | 0 | 0 | 17 | 33 | 33 | 17 | 0 | 0 | 0 | 0 | 0 |
| 11/ 9 | *2.04 | 1.00 | 2.04 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 |
| 11/15 | 0.77 | 0.77 | 0.77 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/22 | 0.87 | 0.51 | 1.32 | 0 | 43 | 14 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/29 | 1.09 | 0.44 | 2.08 | 0 | 29 | 14 | 14 | 29 | 0 | 14 | 0 | 0 | 0 | 0 |
| NOV | 1.06 | 0.44 | 2.08 | 0 | 22 | 22 | 13 | 30 | 4 | 9 | 0 | 0 | 0 | 0 |
| 12/ 4 | *0.79 | 0.38 | 1.16 | 0 | 25 | 50 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12/ 6 | 2.27 | 1.00 | 2.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 0 |
| 12/13 | *0.98 | 0.44 | 2.04 | 0 | 29 | 14 | 43 | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| DEC | 1.05 | 0.38 | 2.27 | 0 | 27 | 18 | 36 | 0 | 0 | 9 | 9 | 0 | 0 | 0 |
| 7/11 | 1.46 | 0.91 | 2.40 | 0 | 0 | 0 | 50 | 25 | 0 | 0 | 0 | 25 | 0 | 0 |
| 7/18 | 1.19 | 0.84 | 1.47 | 0 | 0 | 14 | 29 | 57 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/25 | 1.20 | 0.58 | 1.59 | 0 | 14 | 0 | 29 | 43 | 14 | 0 | 0 | 0 | 0 | 0 |
| JUL | 1.19 | 0.50 | 2.40 | 0 | 8 | 13 | 29 | 42 | 4 | 0 | 0 | 4 | 0 | 0 |
| 8/ 1 | 0.94 | 0.50 | 1.46 | 0 | 14 | 43 | 14 | 29 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 2 | *0.00 | 1.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 0.71 | 0.71 | 0.71 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| STUDY PERIOD | 1.11 | 0.38 | 2.40 | 0 | 17 | 19 | 24 | 29 | 3 | 5 | 2 | 2 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
## MINIMUM WIND YEAR

SITE LOCATION: HELENA　　　　NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

| MONTH | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (F) | AVG WIND POWER DENSITY (W/M2) |
|---|---|---|---|---|
| JAN | 5.4 | 882.8 | 1.1 | 42 |
| FEB | 7.4 | 877.8 | 20.1 | 95 |
| MAR | 8.7 | 880.5 | 34.7 | 100 |
| APR | 10.3 | 878.1 | 42.7 | 131 |
| MAY | 11.5 | 879.4 | 53.2 | 158 |
| JUN | 10.2 | 881.1 | 62.0 | 119 |
| JUL | 9.7 | 882.2 | 69.2 | 86 |
| AUG | 8.6 | 881.1 | 67.7 | 70 |
| SEP | 8.5 | 882.5 | 61.3 | 75 |
| OCT | 8.2 | 881.1 | 47.8 | 77 |
| NOV | 7.2 | 884.5 | 29.0 | 63 |
| DEC | 9.2 | 881.1 | 28.2 | 156 |
| YEARLY AVERAGE:<br>1979 | 8.8 | | | 98 |

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          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                   MEAN WIND YEAR


SITE LOCATION: HELENA             NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/77
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)             (MBS)                 (F)                   (W/M2)
--------------------------------------------------------------------------------------
 JAN         6.8              883.2                18.0                    74

 FEB         8.8              884.2                34.1                   119

 MAR        11.5              876.7                32.4                   182

 APR        10.2              882.8                46.9                   126

 MAY        11.2              876.7                50.4                   144

 JUN        10.9              881.8                63.6                   156

 JUL        11.6              882.8                66.3                   155

 AUG        10.7              882.5                63.6                   121

 SEP         9.0              880.5                56.3                    91

 OCT         8.1              883.2                45.6                    85

 NOV        12.2              880.5                31.2                   269

 DEC         9.0              877.8                20.7                   117

--------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1977       10.0                                                          137
```

## MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
## MAXIMUM WIND YEAR

SITE LOCATION: HELENA NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

| MONTH | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (F) | AVG WIND POWER DENSITY (W/M2) |
|---|---|---|---|---|
| JAN | 11.3 | 877.8 | 18.1 | 240 |
| FEB | 12.3 | 879.4 | 32.8 | 208 |
| MAR | 12.6 | 875.7 | 33.9 | 245 |
| APR | 11.9 | 879.1 | 46.0 | 182 |
| MAY | 12.2 | 878.8 | 48.6 | 204 |
| JUN | 10.9 | 879.4 | 64.9 | 140 |
| JUL | 10.1 | 881.5 | 70.4 | 97 |
| AUG | 8.2 | 882.8 | 61.5 | 61 |
| SEP | 7.6 | 884.9 | 53.5 | 56 |
| OCT | 7.4 | 885.2 | 45.8 | 65 |
| NOV | 8.7 | 882.2 | 34.7 | 125 |
| DEC | 10.2 | 880.5 | 27.7 | 181 |
| YEARLY AVERAGE: | | | | |
| 1974 | 10.3 | | | 149 |

```
           MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                  MINIMUM WIND YEAR

SITE LOCATION: HELENA                NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                        PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
------------------------------------------------------------------------------------------

 JAN     5.4     71   0  10   3   0  10   3   2   1   0   0   0   1   0   0   0   0   0   0

 FEB     7.4     74   0   5   2   0   6   3   3   0   2   2   1   1   0   0   1   0   0   1

 MAR     8.7     63   0  10   4   0   9   3   5   2   1   0   0   1   0   0   1   0   0   0

 APR    10.3     59   0   8   4   0  10   5   6   2   3   2   1   0   0   0   0   0   0   0

 MAY    11.5     48   0   9   5   0  10   5   9   3   6   2   0   2   0   0   0   0   0   0

 JUN    10.2     55   0  11   4   0  12   5   2   5   3   2   1   0   0   0   0   0   0   0

 JUL     9.7     59   0  11   6   0   9   4   5   1   3   0   0   0   0   0   0   0   0   0

 AUG     8.6     64   0  11   7   0   8   3   3   2   1   1   0   0   0   0   0   0   0   0

 SEP     8.5     67   0   8   7   0   4   5   5   0   2   1   0   1   0   0   0   0   0   0

 OCT     8.2     63   0  10   5   0   9   2   5   1   2   1   0   0   0   0   0   0   0   0

 NOV     7.2     68   0   8   4   0   6   7   3   2   2   1   0   0   0   0   0   0   0   0

 DEC     9.2     61   0   6   2   0   7   3   3   5   3   2   0   3   1   0   1   0   0   0

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979    8.8     62   0   9   5   0   8   4   4   2   2   1   0   1   0   0   0   0   0   0
```

```
              MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                     MEAN WIND YEAR

SITE LOCATION: HELENA              NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/77
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                         PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED   <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
------------------------------------------------------------------------------------------

 JAN     6.8    65   0   8   5   0   9   3   4   2   2   2   1   0   0   1   0   0   0   0

 FEB     8.8    59   0   6   5   0   7   3  10   2   3   2   0   2   0   0   0   1   0   0

 MAR    11.5    45   0   7   6   0  11   3  11   5   5   5   0   1   0   0   0   0   0   0

 APR    10.2    47   0  11   5   0  12   7   8   5   5   3   1   0   0   0   0   0   0   0

 MAY    11.2    46   0  10   7   0  10   7  10   3   5   1   0   1   0   0   0   0   0   0

 JUN    10.9    53   0  11   4   0  10   4   4   3   5   1   1   4   0   0   1   0   0   0

 JUL    11.6    46   0  12   6   0   9   6   9   2   5   3   0   2   1   0   0   0   0   0

 AUG    10.7    58   0  14   5   0   6   4   4   2   3   2   0   1   1   0   0   0   0   0

 SEP     9.0    60   0  12   5   0   9   3   3   2   2   1   0   1   0   0   0   0   0   0

 OCT     8.1    69   0   6   3   0   6   5   4   1   0   1   1   1   0   0   0   0   0   0

 NOV    12.2    45   0   6   4   0  10   4   8   5   6   3   0   4   2   0   1   0   0   0

 DEC     9.0    54   0  10   7   0  11   6   3   4   3   3   0   2   0   0   0   0   0   0

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1977   10.0    53   0   9   5   0   9   5   6   3   4   2   0   2   0   0   0   1   0   0
```

```
          MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                MAXIMUM WIND YEAR

SITE LOCATION: HELENA              NCC WEATHER STATION LOCATION: HELENA
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                   PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED   <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
------------------------------------------------------------------------------------------

 JAN   11.3     41   0   7   6   0   9   5   9   6   7   5   0   2   3   0   1   1   1   0

 FEB   12.3     43   0   6   8   0   8   5  12   4   8   3   0   2   0   0   0   0   0   0

 MAR   12.6     46   0   6   5   0  11   4   9   4   4   5   2   2   2   2   0   0   0   0

 APR   11.9     49   0   6   5   0   9   4  11   5   5   1   0   5   0   0   0   0   0   0

 MAY   12.2     44   0  11   7   0  11   7   7   2   3   2   0   4   1   1   1   0   0   0

 JUN   10.9     54   0  12   4   0  10   2   6   2   4   2   0   1   2   0   0   0   0   0

 JUL   10.1     58   0  10   9   0   9   4   1   3   3   1   0   1   0   0   0   0   0   0

 AUG    8.2     72   0  10   3   0   7   4   1   1   1   1   0   0   0   0   0   0   0   0

 SEP    7.6     73   0   5   8   0   6   4   3   1   1   1   1   1   0   0   0   0   0   0

 OCT    7.4     75   0   6   2   0   7   2   3   1   2   0   0   1   0   0   0   0   0   0

 NOV    8.7     68   0   6   3   0   5   3   5   1   4   2   3   0   1   2   0   0   0   0

 DEC   10.2     56   0   5   4   0   6   5   7   3   7   3   0   2   0   1   0   0   0   0

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974  10.3     56   0   8   5   0   8   4   6   3   4   2   1   2   1   0   0   0   0   0
```

# APPENDIX I

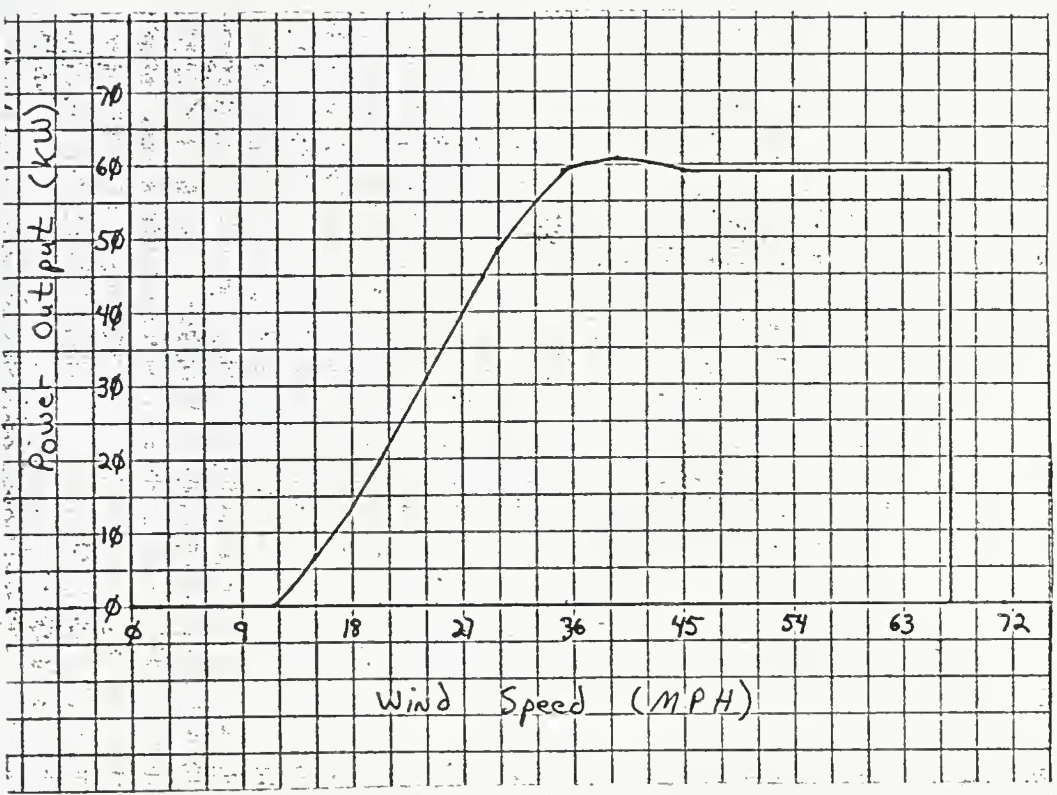
## Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon; Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

# APPENDIX II

## Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
## Wind Speed Versus Generator KWh Output



# APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
    - a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
    - b) the total amount of your proposed investment.
        - i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
        - ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
        - iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   c) Complete warranty information.
   d) Complete information for utility/home electric interface connection.
   e) Maintenance schedules and their costs.
   f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

## III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

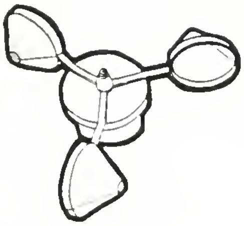
If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

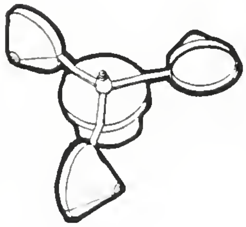
Then, here, in general, are the steps to getting those first kilowatts flowing:

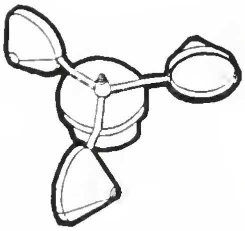
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

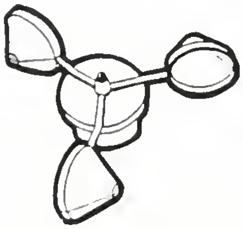
4 ) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.
5 ) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6 ) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7 ) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The Torgerson Place, Lambert, MT
## July 19, 1981 - October 22, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

# ACKNOWLEDGEMENTS

Gunderson Consulting Service is grateful to all those people who assisted in preparing this report.

We commend the Montana Legislature for allocating funds from the coal severence tax income to further the research, development and demonstration of all renewable energy resources and thank the Renewable Alternative Energy Advisory Council for awarding us this grant. We would like to mention the names of people on the staff of the Renewable Energy Bureau at DNRC who gave help and encouragement to this project--Jim Iverson, Mike Chapman, Georgia Brensdal, Jeannie Thurston, Dave Dysinger, Greg Mills and John Orndorff.

We also wish to acknowledge the contribution of the site owners, who diligently charged and changed the systems' batteries, gathered the data and forwarded it to DNRC for storage. They are: Jim Salmond, Marcel Solum, Chuck and Karen Davis, Dave Hastings, Jerry McGillivray, Helen and Gordon Waller, Dan Heckford, Randy Moy, Pat and Ken Torgerson, Witt Hibbard and the Sieben Livestock Company, David Erickson and Ken Morrow.

The people at Gunderson Consulting who contributed to this project are: Marylore Lahey, Seana Lahey, Al Gunderson, Ken Walters, Abby and Egypt Katz and Dana Gunderson.

Both Charless Fowlkes and John Obermeier contributed expert advice which greatly added to the quality and accuracy of the material in this report.

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #DSR-3 at the Pat and Ken Torgerson place near Lambert, Montana from July 19, 1981 to October 22, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensor used in the system which gathered this data. The system included a dual-channel strip chart recorder housed in a plastic case, a 4-pole cup anemometer, a wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensor to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The wind direction sensor failed to operate during the period.

The operating specifications for the anamometer are:
Wind velocity range: 3- 150 MPH
Temperature range -60 to 200 degrees F.

The operating specifications for the strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The the strip chart recorder records a wind speed reading every two seconds by making a mark on the strip chart. To make the mark, an impact bar strikes the top side of the meter needle, which then touches pressure- sensitive paper (a "strip chart") moving slowly beneath the needle. These dots accumulate on the moving paper forming a graph of the wind speed.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On July 19, 1981, under contract with DNRC, Gunderson Consulting installed DNRC's wind monitoring system #DSR-3 at the Torgerson farm northwest of Lambert (mailing address: Lambert, Montana, 59243). Between the date of installation and October 22, 1981, the Torgersons charged the batteries and changed the rolls of strip chart paper as they were filled. The anemometer and the strip chart recorder worked according to specifications during the monitoring period but the wind direction sensor failed to send any signals to the recorder.

In June 1982, DNRC contracted with Gunderson Consulting to analyze and summarize the data on the strip charts and prepare this report.

To locate the monitoring site, drive west from Lambert on State 200 about one mile to a large 4-H sign. Turn north onto a gravel road and drive one and one-half miles; then turn west and drive one mile; then turn south and drive about a quarter of a mile to the farm at the end of the road.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

No wind direction summaries could be prepared, due to the failure of the wind direction sensor to transmit any data.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Williston, ND) is at 6.10 meters while the anemometer at the site was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \frac{H}{h}^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these average daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two geographically separated locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to a sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten year period. In this process, both wind speed and wind power density were projected, by applying the monitoring period correlation factor to the wind speed data from the previous ten years at the National Weather Service Station in Williston, North Dakota. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three-hourly averages were maintained for both the monthly and yearly averages.

The most useful statistic to compare the potential of several sites is the wind power density. But even though wind power density is by far the most useful statistical tool for wind generator site selection, it is usually the least used by wind developers. Wind power density is defined as:

$$P= (1/2)pkV^{3}$$

where P = wind power density
p = air density

V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density $p$ is defined as: $p = A/(RT)$
where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is a better basis than average wind speed for selecting a site for a wind generator becomes clear through understanding the equation for wind power density given above. It shows that the power in the wind and, therefore, the power that can be absorbed from the wind by a wind generator, is proportional to the cube of the wind speed. If an average wind speed is used to calculate the wind power density, the average speed mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale. When the average speed is cubed it will yield a much lower value than if each instantaneous wind speed were cubed and then all the cubed speeds averaged. The following example illustrates this fact: averaging the following numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level, assuming the site elevation does not significantly differ from that at the National Weather Service Station.

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed. The only difference being that the data being summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for a description of this method.

## How to Use This Data

First, refer to Appendix I to get an idea of how the average wind power density at your site compares with the density at other locations in Montana. A comparison of wind power densities gives the best perspective on the relative potential of several sites.

If you were encouraged by the comparison, you should follow the procedure below to calculate a hypothetical yearly power output of a particular wind generator if it were installed at your site. This procedure uses a wind generator's Power Characteristic Curve and a yearly average wind speed percentage profile. In our example, we use a hypothetical yearly average wind speed profile and the curve for a Windmatic 14S generator, given in Appendix II. In your calculations, you would use the actual yearly average wind speeds given in this report at the bottom of the chart titled, "Monthly & Yearly Avg Wind Spd (MPH) and Percentage Profile--Mean Wind Year", and either the Windmatic's curve from Appendix II or one you get for a different generator.

PERCENT OF WIND IN VELOCITY BRACKETS (hypothetical)

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these percentage figures into the number of hours per year the wind blew in each bracket. Multiply the value in the first percentage bracket (41%, = .41) by the number of hours in a year (365 X 24 = 8,760 hours). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds of 10 MPH or less. In the second bracket (10 to 10.99 MPH), the wind blew .05 X 8,760 = 438 hours. Apply this process to each bracket of the spectrum, and the result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

You will use the numbers of hours in Step 3.

The second step is to fit the Power Characteristic Curve beneath the midpoints given below. If you are using the Windmatic's curve, you can use the table below just as it is.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KWH) FROM POWER CHARACTERISTIC CURVE

The third step is to multiply the number of hours in each bracket (Step 1) by the corresponding generator output in each bracket (Step 2). These products are shown below the line:

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

```
------------------------------------------------------------------------------
0   0   0  701  1752  7358  9636  7446  5519  4730  2891  3416  3942  4380  0 ...
                    PERIOD GENERATOR OUTPUT (KWH) PER BRACKET
```

and then add the outputs from all the brackets. This gives the hypothetical yearly generator output, which in this example is 51,771 kWh.

Now you are ready to estimate the yearly dollar value of the electricity that a particular generator would theoretically produce if it were installed at your site. Multiply the total generator output (51,771 kWh) by your local utility's current electric rate (honk if you love puns). In this example we use $.0625/kWh but you will have to get the actual residential rate from your local utility. $.0625 x 51,771 = $3,235.69 annual value, sometimes referred to as "displaced cost", of the electricity generated in this hypothetical case.

* * * * *

The value of the displaced electricity and the cost of the generator are two of the factors you have to consider if you want to make a realistic evaluation of the economics of wind electric generation. There are many others: cost of site preparation (land rental, road improvement, power line installation and connection); legal fees, charges for pouring the foundation and erecting the tower, inspection fees, system checkout, insurance, shipping, maintenance and always at least one more item that no one thought of. Below, from the Solar Energy Research Institute in Golden, Colorado, is a breakdown of the cost to be expected in a large scale wind development:

| | |
|---|---|
| Generator and Blade Assembly - | 57% |
| Tower and Site Access - | 11% |
| Foundation/Site Preparation - | 9% |
| Operations/Maintenance - | 9% |
| Assembly/Checkout - | 8% |
| Other - | 4% |
| Equipment Transportation - | 2% |

Source: publication SERI/SP-732-728, the Solar Energy Research Institute, October 1980.

# HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH; etc.

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors", which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors. There is no percentage spectrum, or minimum or maximum correlation factor for each reading period since only one correlation factor is generated given the nature of the data stored by a compilator. Since only one value is generated a spectrum distribution and minimum or maximum values have no meaning.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50; i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But these estimate wind speed averages likely to occur at the site and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: LAMBERT TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 7/19/81

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
| 7/25 | 8.9 | 65 | 11 | 8 | 5 | 3 | 6 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| JUL | 9.5 | 58 | 11 | 6 | 6 | 5 | 8 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 1 | 10.7 | 49 | 10 | 5 | 7 | 6 | 11 | 7 | 4 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 8 | 9.0 | 63 | 8 | 5 | 10 | 5 | 3 | 4 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 9 | * 8.1 | 78 | 6 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 9.4 | 61 | 8 | 6 | 8 | 4 | 3 | 6 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/12 | 9.0 | 64 | 6 | 3 | 5 | 5 | 8 | 5 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/19 | 9.0 | 59 | 9 | 8 | 10 | 5 | 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9/26 | 12.5 | 40 | 2 | 4 | 8 | 5 | 10 | 9 | 7 | 5 | 6 | 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| SEP | 10.2 | 54 | 6 | 5 | 7 | 5 | 7 | 4 | 3 | 2 | 2 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| 10/ 3 | 9.3 | 67 | 8 | 5 | 3 | 4 | 4 | 4 | 1 | 1 | 1 | 0 | 1 | 0 | 2 | 2 | 1 | 0 | 0 |
| 10/ 4 | * 3.7 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/ 6 | 7.0 | 71 | 7 | 11 | 4 | 0 | 0 | 4 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/13 | 14.3 | 24 | 5 | 8 | 7 | 10 | 13 | 9 | 6 | 7 | 4 | 2 | 2 | 3 | 1 | 1 | 0 | 0 | 0 |
| 10/20 | 12.3 | 35 | 5 | 6 | 7 | 10 | 13 | 8 | 4 | 5 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10/22 | *11.3 | 43 | 3 | 11 | 3 | 9 | 9 | 6 | 6 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 11.4 | 43 | 5 | 7 | 5 | 8 | 10 | 7 | 4 | 5 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

## WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: LAMBERT
TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 7/19/81

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 7/25 | 8.9 | | | 49 |
| JUL | 9.5 | 946.8 | 73.8 | 64 |
| 8/ 1 | 10.7 | | | 95 |
| 8/ 8 | 9.0 | | | 62 |
| 8/ 9 | * 8.1 | | | 33 |
| AUG | 9.4 | 948.5 | 74.3 | 75 |
| 9/12 | 9.0 | | | 77 |
| 9/19 | 9.0 | | | 72 |
| 9/26 | 12.5 | | | 189 |
| SEP | 10.2 | 949.2 | 61.8 | 127 |
| 10/ 3 | 9.3 | | | 130 |
| 10/ 4 | * 3.7 | | | 4 |
| 10/ 6 | 7.0 | | | 48 |
| 10/13 | 14.3 | | | 256 |
| 10/20 | 12.3 | | | 178 |
| 10/22 | *11.3 | | | 143 |
| OCT | 11.4 | 945.8 | 45.4 | 170 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

```
              WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  LAMBERT                      TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:   7/19/81

                                               PERCENTAGE WIND SPEED PROFILE
  DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-------------------------------------------------------------------------------------------------
   19     *12.0  7 HRS    29   0  43   0   0  14   0   0   0  14   0   0   0   0   0   0   0   0
   20       6.7           75  17   0   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   21       7.1           88   8   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0
   22       8.4           75  17   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   23       6.5           96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   24       9.7           54   8   8  13   4   8   4   0   0   0   0   0   0   0   0   0   0   0
   25      12.2           13  13  21  17  13  25   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  8.9           65  11   8   5   3   6   1   0   0   1   0   0   0   0   0   0   0   0

   26      10.3           50  21   4   4   0  17   4   0   0   0   0   0   0   0   0   0   0   0
   27      11.2           38   4   0   0  29  25   4   0   0   0   0   0   0   0   0   0   0   0
   28      11.9           25  21  13  13   8  17   4   0   0   0   0   0   0   0   0   0   0   0
   29       8.0           67  13   4  13   0   0   4   0   0   0   0   0   0   0   0   0   0   0
   30      11.6           50   0   0   4   4   8  13  17   4   0   0   0   0   0   0   0   0   0
   31       8.2           75   8   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
-------------------------------------------------------------------------------------------------
  JUL       9.5           58  11   6   6   5   8   3   1   0   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  0000 HOURS
STARTING DATE:   8/ 1/81

                                              PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
    1       13.6         38   4   4   4   0   8  21   8   8   0   0   4   0   0   0   0   0   0

WKLY AVG=> 10.7          49  10   5   7   6  11   7   4   2   0   0   1   0   0   0   0   0   0

    2        8.8         67   8   0  13   8   0   0   0   4   0   0   0   0   0   0   0   0   0
    3        6.1         92   4   0   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4        8.8         79   8   0   0   0   0   4   0   8   0   0   0   0   0   0   0   0   0
    5       10.7         50   8   4   8  13   4   4   0   4   4   0   0   0   0   0   0   0   0
    6       10.0         42  13  13  25   8   0   0   0   0   0   0   0   0   0   0   0   0   0
    7       10.7         46   4  13   0   4  13  21   0   0   0   0   0   0   0   0   0   0   0
    8        7.7         63  13   4  17   0   4   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.0          63   8   5  10   5   3   4   0   2   1   0   0   0   0   0   0   0   0

    9      * 8.1 18 HRS  78   6  17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   10      NO DATA
   11      NO DATA
   12      NO DATA
   13      NO DATA
   14      NO DATA
   15      NO DATA

WKLY AVG=>  8.1          78   6  17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  AUG        9.4         61   8   6   8   4   3   6   1   3   0   0   0   0   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
       THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  3
STARTING TIME:  1400 HOURS
STARTING DATE:   9/ 6/81

                                          PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
    6    *10.0 10 HRS    50  10  20  10   0  10   0   0   0   0   0   0   0   0   0   0   0   0
    7     10.6           46   8   4   0   4  17  21   0   0   0   0   0   0   0   0   0   0   0
    8      7.7           63   0   0   8   8  21   0   0   0   0   0   0   0   0   0   0   0   0
    9      8.6           63   8   0   8  13   8   0   0   0   0   0   0   0   0   0   0   0   0
   10      7.1           83   4   0   0   4   0   4   0   4   0   0   0   0   0   0   0   0   0
   11     10.7           54   8   4   0   0   0   4  17   0   8   4   0   0   0   0   0   0   0
   12      8.2           79   4   4   8   0   4   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.0          64   6   3   5   5   8   5   3   1   1   1   0   0   0   0   0   0   0

   13      9.8           58   0   0  17  13  13   0   0   0   0   0   0   0   0   0   0   0   0
   14     14.0            0   4  29  29  21   4   0   0   4   0   4   0   4   0   0   0   0   0
   15     10.0           63   4   4   8   0   8   0   4   0   4   0   4   0   0   0   0   0   0
   16      6.8           79  21   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   17      9.8           46  25  17   8   0   4   0   0   0   0   0   0   0   0   0   0   0   0
   18      7.3           71   4   8   4   4   4   4   0   0   0   0   0   0   0   0   0   0   0
   19      5.0           96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.0          59   9   8  10   5   5   1   1   1   1   1   1   1   0   0   0   0   0

   20     13.6           33   0   0  13   8  13   4  25   0   4   0   0   0   0   0   0   0   0
   21      9.6           63   0   4   4   0   4   4   0   4   4   8   4   0   0   0   0   0   0
   22     12.2           33   4   0   4   8   8  29  13   0   0   0   0   0   0   0   0   0   0
   23      7.9           75   4   4   0   4   4   8   0   0   0   0   0   0   0   0   0   0   0
   24      8.5           67   4   0   4   4  13   8   0   0   0   0   0   0   0   0   0   0   0
   25     16.2            0   0  21  25   4  17   4   0   4  17   8   0   0   0   0   0   0   0
   26     19.2            8   0   0   4   8   8   4  13  25  17   4   4   0   4   0   0   0   0

WKLY AVG=> 12.5          40   2   4   8   5  10   9   7   5   6   3   1   0   1   0   0   0   0

   27     16.6           42   4   4   8   4   0   0   0   0   4   0   4   0  13  13   4   0   0
   28     12.8           17  17   8   8  17  17  13   0   4   0   0   0   0   0   0   0   0   0
   29      6.2           83   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   30      6.4           83  13   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
-----------------------------------------------------------------------------------------------
  SEP     10.2           54   6   5   7   5   7   4   3   2   2   1   1   0   1   1   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  4
STARTING TIME:  0000 HOURS
STARTING DATE:  10/ 1/81

                                              PERCENTAGE WIND SPEED PROFILE
  DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------
   1        9.4           67   0   0   4   4   8  13   4   0   0   0   0   0   0   0   0   0   0
   2        8.1           75  13  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   3        5.8          100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.3           67   8   5   3   4   4   4   1   1   1   0   1   0   2   2   1   0   0

   4       * 3.7 13 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   5        NO DATA
   5       * 6.4  4 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   6        7.6           67   8  13   4   0   0   4   0   4   0   0   0   0   0   0   0   0   0

WKLY AVG=>  5.9           80   5   7   2   0   0   2   0   2   0   0   0   0   0   0   0   0   0

   7       14.6            4   0   8  21  21  21   4  13   8   0   0   0   0   0   0   0   0   0
   8       12.7           33  13   8   4   4  17   0   0   8   4   4   0   4   0   0   0   0   0
   9       14.2           21   8  13   4  13   8  13   8   4   0   4   4   0   0   0   0   0   0
  10        6.2           88   4   0   0   4   0   0   0   4   0   0   0   0   0   0   0   0   0
  11       14.7            8   8   8   8  13  17  25   4   4   4   0   0   0   0   0   0   0   0
  12       18.1            8   0   8   0   8  13  17  13   8   8   8   4   4   0   0   0   0   0
  13       19.5            8   0   8   8   8  13   4   4   8   8   0   4  13   4   8   0   0   0

WKLY AVG=> 14.3           24   5   8   7  10  13   9   6   7   4   2   2   3   1   1   0   0   0

  14        8.1           67   4   0   8   8  13   0   0   0   0   0   0   0   0   0   0   0   0
  15        9.7           42  17   8  13   8   8   4   0   0   0   0   0   0   0   0   0   0   0
  16        7.0           71   0   8   4   8   8   0   0   0   0   0   0   0   0   0   0   0   0
  17       19.7            0   0   4   0   0  25  17  13  13   4   0  17   8   0   0   0   0   0
  18       11.6           33  13   4   4  13  25   4   0   4   0   0   0   0   0   0   0   0   0
  19       13.7           29   0  13  17   0   0  17   4  17   0   4   0   0   0   0   0   0   0
  20       16.6            4   4   4   0  29  13  13   8   4  13   8   0   0   0   0   0   0   0

WKLY AVG=> 12.3           35   5   6   7  10  13   8   4   5   2   2   2   1   0   0   0   0   0

  21       12.7           42   4  13   0   8   0   8   8  13   4   0   0   0   0   0   0   0   0
  22       * 9.8 11 HRS   45   0   9   9   9  27   0   0   0   0   0   0   0   0   0   0   0   0
  23        NO DATA
  24        NO DATA
  25        NO DATA
  26        NO DATA
  27        NO DATA

WKLY AVG=> 11.3           43   3  11   3   9   9   6   6   9   3   0   0   0   0   0   0   0   0

-----------------------------------------------------------------------------------------------
  OCT      11.4           43   5   7   5   8  10   7   4   5   2   1   1   1   0   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

## MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: LAMBERT NCC WEATHER STATION LOCATION: WILLISTON
DNRC TOWER HEIGHT: 10.0 METERS
NCC TOWER HEIGHT: 6.1 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 7/19/81

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION | FACTORS-> | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 7/25 | 1.15 | 0.79 | 1.57 | 0 | 0 | 29 | 29 | 29 | 14 | 0 | 0 | 0 | 0 | 0 |
| JUL | 1.17 | 0.79 | 1.57 | 0 | 0 | 23 | 23 | 46 | 8 | 0 | 0 | 0 | 0 | 0 |
| 8/ 1 | 1.20 | 0.84 | 1.44 | 0 | 0 | 14 | 14 | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/ 8 | 1.13 | 0.88 | 1.53 | 0 | 0 | 14 | 57 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| 8/ 9 | *0.91 | 0.91 | 0.91 | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| AUG | 1.12 | 0.88 | 1.53 | 0 | 0 | 11 | 56 | 22 | 11 | 0 | 0 | 0 | 0 | 0 |
| 9/12 | 1.19 | 0.60 | 1.57 | 0 | 14 | 0 | 14 | 57 | 14 | 0 | 0 | 0 | 0 | 0 |
| 9/19 | 1.11 | 0.90 | 1.51 | 0 | 0 | 0 | 71 | 0 | 29 | 0 | 0 | 0 | 0 | 0 |
| 9/26 | 1.29 | 1.00 | 1.58 | 0 | 0 | 0 | 29 | 57 | 14 | 0 | 0 | 0 | 0 | 0 |
| SEP | 1.21 | 0.60 | 1.76 | 0 | 4 | 8 | 32 | 32 | 24 | 0 | 0 | 0 | 0 | 0 |
| 10/ 3 | 0.99 | 0.29 | 1.76 | 14 | 0 | 43 | 14 | 0 | 29 | 0 | 0 | 0 | 0 | 0 |
| 10/ 4 | *0.43 | 0.43 | 0.43 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/ 6 | 0.76 | 0.76 | 0.76 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/13 | 1.24 | 0.62 | 1.71 | 0 | 0 | 14 | 29 | 29 | 29 | 0 | 0 | 0 | 0 | 0 |
| 10/20 | 0.96 | 0.48 | 1.23 | 0 | 14 | 0 | 71 | 14 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10/22 | *0.88 | 0.72 | 1.05 | 0 | 0 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OCT | 0.97 | 0.29 | 1.71 | 5 | 10 | 19 | 43 | 14 | 10 | 0 | 0 | 0 | 0 | 0 |
| STUDY PERIOD | 1.11 | 0.29 | 1.76 | 1 | 4 | 15 | 37 | 28 | 15 | 0 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

```
        MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MEAN WIND YEAR

SITE LOCATION: LAMBERT            NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/75
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE       AVG TEMPERATURE    AVG WIND POWER DENSITY
           (MPH)              (MBS)                (F)                 (W/M2)
-------------------------------------------------------------------------------------
 JAN       11.1               944.5                12.0                 224

 FEB       13.6               947.5                12.3                 242

 MAR       14.1               945.1                21.9                 310

 APR       13.3               945.5                34.7                 287

 MAY       13.7               944.1                52.9                 275

 JUN       13.0               942.4                62.1                 214

 JUL       10.7               945.5                73.0                 134

 AUG       12.7               946.2                65.3                 197

 SEP       13.0               949.9                55.0                 271

 OCT       12.1               944.5                44.4                 192

 NOV       10.7               947.2                28.4                 139

 DEC       11.6               947.5                15.7                 236

-------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1975      12.5                                                         226
```

## MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
## MINIMUM WIND YEAR

SITE LOCATION: LAMBERT NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA: 200 HOURS ON 1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

| MONTH | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (F) | AVG WIND POWER DENSITY (W/M2) |
|---|---|---|---|---|
| JAN | 11.6 | 950.9 | -2.2 | 221 |
| FEB | 12.8 | 949.5 | 1.7 | 261 |
| MAR | 13.2 | 947.2 | 23.0 | 327 |
| APR | 13.5 | 945.8 | 34.6 | 226 |
| MAY | 13.2 | 945.8 | 49.2 | 240 |
| JUN | 12.2 | 945.8 | 65.0 | 189 |
| JUL | 9.8 | 947.2 | 70.3 | 110 |
| AUG | 10.8 | 946.5 | 66.9 | 120 |
| SEP | 11.3 | 946.8 | 61.1 | 147 |
| OCT | 12.3 | 945.1 | 46.7 | 224 |
| NOV | 8.9 | 948.9 | 25.1 | 113 |
| DEC | 9.8 | 946.5 | 23.8 | 189 |
| YEARLY AVERAGE:<br>1979 | 11.6 | | | 196 |

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                   MAXIMUM WIND YEAR

SITE LOCATION: LAMBERT              NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/78
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED      AVG PRESSURE       AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)               (MBS)                (F)                  (W/M2)
-----------------------------------------------------------------------------------
 JAN        11.0               954.3                -2.5                  191

 FEB        14.1               952.6                 7.7                  385

 MAR        11.7               947.5                27.8                  189

 APR        16.2               945.1                43.0                  460

 MAY        13.5               943.4                57.2                  244

 JUN        10.8               945.1                63.8                  139

 JUL        12.4               946.2                68.6                  184

 AUG        12.1               945.1                67.5                  178

 SEP        13.2               943.8                60.2                  274

 OCT        14.2               947.5                46.4                  346

 NOV        11.9               949.9                20.8                  265

 DEC        15.1               945.1                 8.3                  442

-----------------------------------------------------------------------------------
YEARLY AVERAGE:
 1978       13.0                                                          272
```

```
         MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                  MEAN WIND YEAR


SITE LOCATION: LAMBERT              NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/75
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                           PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED     <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
--------------------------------------------------------------------------------------------

 JAN    11.1      50   0   9   3   0  11   6   4   3   7   1   0   1   1   2   0   0   0   0

 FEB    13.6      30   0   9   5   0  18   8  14   8   3   1   0   2   1   0   0   0   0   0

 MAR    14.1      32   0   7   6   0  15   5  13   8   3   3   1   3   0   2   0   1   0   0

 APR    13.3      32   0   9   2   0  20   7  10   6   4   2   0   3   0   1   1   1   0   0

 MAY    13.7      35   0   7   7   0  15   7   6   7   6   3   1   4   0   1   0   0   0   0

 JUN    13.0      33   0  11   4   0  16  10  10   5   5   3   1   2   1   0   0   0   0   0

 JUL    10.7      38   0  14   6   0  16   8   8   4   3   1   0   1   0   0   0   0   0   0

 AUG    12.7      33   0   9   7   0  15   7  11   5   8   2   1   2   0   0   0   0   0   0

 SEP    13.0      33   0  13   6   0  12   8   8   4   7   1   1   2   1   2   1   0   0   0

 OCT    12.1      43   0  10   6   0  11   7   7   4   5   2   2   2   0   0   0   0   0   0

 NOV    10.7      47   0  13   6   0  10   4  10   5   5   0   0   0   0   0   0   0   0   0

 DEC    11.6      51   0   8   2   0  10   4   8   2   5   4   0   5   1   1   0   0   0   0

--------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1975   12.5      38   0  10   5   0  14   7   9   5   5   2   1   2   1   1   0   0   0   1
```

```
                 MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                        MINIMUM WIND YEAR


SITE LOCATION: LAMBERT              NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                           PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-----------------------------------------------------------------------------------------------

 JAN    11.6     46   0   7   5   0  10   6  13   3   4   2   1   2   0   2   0   0   0   0

 FEB    12.8     41   0   8   7   0  11   5   8   2   8   4   2   1   1   0   0   0   0   0

 MAR    13.2     36   0  10   8   0  14   4   8   4   5   1   4   1   0   1   1   0   1   1

 APR    13.5     28   0  12  10   0  16   7  10   6   4   2   2   1   0   0   0   0   0   0

 MAY    13.2     31   0   7   8   0  17   7   9   7   6   3   1   2   2   0   0   0   0   0

 JUN    12.2     42   0  10   8   0  10   6   8   4   4   3   1   2   1   0   0   0   0   0

 JUL     9.8     57   0  10   5   0   8   5   7   3   3   1   0   0   0   0   0   0   0   0

 AUG    10.8     49   0   8   8   0  11  11   6   3   4   0   0   0   0   0   0   0   0   0

 SEP    11.3     50   0   8   6   0   9   5  13   3   3   2   0   0   0   0   0   0   0   0

 OCT    12.3     43   0   9   4   0  11   7  11   4   4   4   0   2   0   0   0   0   1   0

 NOV     8.9     60   0   6   8   0   7   5   5   3   4   2   0   1   0   1   0   0   0   0

 DEC     9.8     59   0   8   4   0   9   1   5   2   4   3   0   0   0   1   1   0   1   0

-----------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979   11.6     45   0   9   7   0  11   6   9   4   4   2   1   1   0   1   0   0   0   1
```

```
        MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                              MAXIMUM WIND YEAR

SITE LOCATION: LAMBERT            NCC WEATHER STATION LOCATION: WILLISTON
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/78
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 1.11
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                          PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-----------------------------------------------------------------------------------------------

 JAN    11.0     51   0   9   4   0  12   1   9   3   6   2   1   1   0   0   0   0   0   0

 FEB    14.1     34   0  11   5   0  10   4   9   3   7   3   1   6   3   0   1   0   1   0

 MAR    11.7     41   0  10   7   0  19   4   8   4   2   1   0   0   1   0   1   0   0   0

 APR    16.2     23   0  10   6   0  11   5  12   7  12   2   3   5   2   1   0   0   0   2

 MAY    13.5     35   0   6   6   0  12   8  14   6   5   4   2   1   1   0   0   0   0   0

 JUN    10.8     55   0   7   7   0  10   3   8   2   5   1   0   0   0   0   0   0   0   0

 JUL    12.4     44   0   9   6   0  14   3  11   5   3   2   1   2   1   0   0   0   0   0

 AUG    12.1     38   0   7   8   0  13   6  13   7   4   2   0   0   0   0   0   0   0   0

 SEP    13.2     37   0  13   4   0  13   6   4   4   8   2   1   4   0   2   0   0   0   0

 OCT    14.2     35   0   5   8   0  15   5  11   5   7   2   0   3   0   1   0   0   0   1

 NOV    11.9     44   0   6   7   0  13   7   4   6   6   2   0   1   0   1   0   0   1   1

 DEC    15.1     35   0   5   7   0  13   5   9   5   5   4   0   3   1   3   3   0   0   1

-----------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1978   13.0     39   0   8   6   0  13   5   9   5   6   2   1   2   1   1   1   1   0   1
```

## APPENDIX I

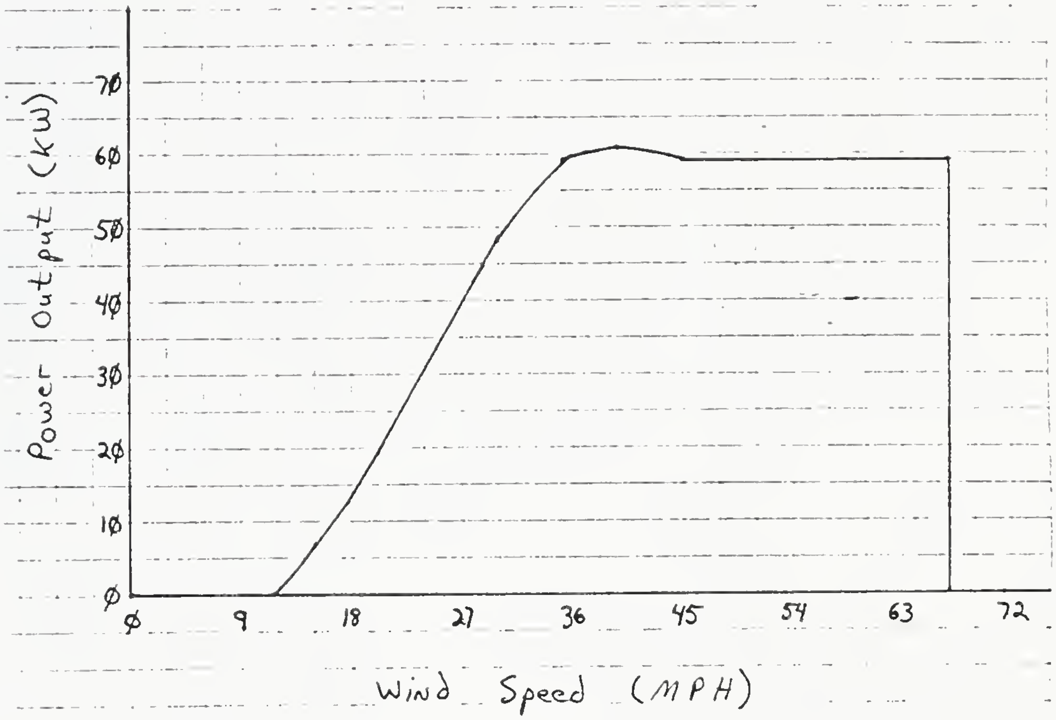
### Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon, Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

# APPENDIX II

## Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator Wind Speed Versus Generator KWh Output



## APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   - a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   - b) the total amount of your proposed investment.
     - i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
     - ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
     - iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   - a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   - b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   - c) Complete warranty information.
   - d) Complete information for utility/home electric interface connection.
   - e) Maintenance schedules and their costs.
   - f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   - g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   - h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

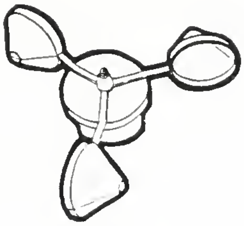
If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

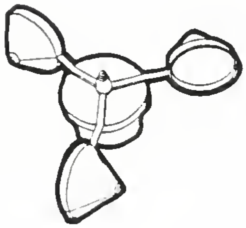
Then, here, in general, are the steps to getting those first kilowatts flowing:

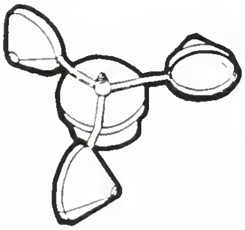
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

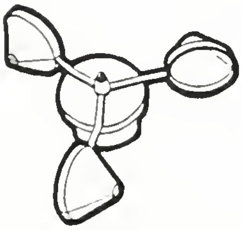
4) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.
5) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The Dan Heckford Place, Power, MT

June 20, 1981 - October 18, 1981

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered by DNRC's compilator system at the Dan Heckford place near Power, Montana from June 20, 1981 to October 18, 1981.

Natural Power Inc., New Boston, New Hampshire, manufactured the compilator and sensors in the system which includes: a Series A30 low-temperature data compilator ("Compilator I"); a model A75-104 four-pole cup anemometer; a 12-volt wet cell automobile battery, and the cables needed to connect the sensor to the Compilator, the Compilator to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The operating specifications for the model A75-301 direction sensor are:
Temperature range: -55 to 170 degrees F
Resolution: 45 degrees
Maximum wind speed: 150 MPH

The operating specifications for the model A75-104 anemometer are:
Wind velocity range: 3-150 MPH
Temperature range -60 to 200 degrees F.

The operating specifications for the Series A30 Compilator I are:
Temperature range: -40 to 70 degrees C.
Recorder accuracy: + or - 1%
Compilator clock: + or - 15 minutes/month
Response time: 1 second

The Compilator I separates wind speeds of 0 to 62 MPH into thirty-one discrete increments of 2 MPH each (speeds of 62 MPH or more are grouped together into the thirty-second increment) then counts and stores the number of seconds the wind speed is blowing in each increment. Periodically, the site owner copies the stored information from a digital display in the front panel onto a data log and erases the compilator memory so it can accumulate fresh data.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The insulated wooden instrument shelter located at the base of the tower housed the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four-foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On January 19, 1981, under contract with DNRC, Gunderson Consulting installed DNRC's compilator system at the Dan Heckford place southeast of Power, Montana (mailing address: Route 2, Power, Montana, 59468). On about March 1, 1981, Gunderson Consulting determined that the compilator was not functioning properly, removed it and, on March 8, shipped it to the manufacturer for repair. The manufacturer returned a new unit to DNRC which Gunderson Consulting installed at the Heckford Place on June 20, 1981. During the two monitoring periods, Dan Heckford logged the data, re-charged the battery, assisted in installing and removing the two compilators and in making repairs when the boom of a crop sprayer hooked a guy wire and pulled the tower down. The new compilator ran from June 20, 1981 to October 18, 1981 and produced reliable data. Mr. Heckford turned his data log over to Gunderson Consulting at the end of the monitoring period. In June, 1982, DNRC contracted with Gunderson Consulting to analyze and summarize the data.

To locate the monitoring site, take north-bound Interstate Highway 15 from Great Falls and exit at Gordon, seven miles north of Vaughan. Travel north on the frontage road two miles, then turn west onto a gravel road. The Heckford Place is located approximately one-fourth mile from this turn, on the north side of the road.

## Description the Data Analysis Procedure

Analysis of the compilator data was done on a computer system of the following components: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, and an Integral Data System, Inc. model 440 dot-matrix impact printer.

The data for each reading period was entered into the computer and stored in a data file on a 5.25 inch floppy disk. Using this data another program calculated the average wind speed for each reading period and for the entire monitoring period. To minimize errors in averaging the monitoring period speed, separate running totals were maintained for each of the compilator's 32 wind speed brackets or "bins".

From the data in the bins, a wind speed percentage spectrum was calculated by adding together the contents of a single bin or several bins, then dividing that total by the total of all 32 bins. This calculation produces the percent of time the wind blew in each percentage spectrum bracket during a reading period. The sizes of the wind speed percentage brackets were set to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer used the wind speed averages to calculate wind power density values for each reading period and the entire monitoring period. Note that these values cannot be a very accurate description of the wind power potential at the site, since they result from long-term wind speed averages. The longer the time period of wind speed average used in calculting wind power density, the more unrelible the value generated is. A more detailed description of the calculation of wind power density will be given later in this report.

To correlate data from this monitoring site with data from the nearest National Weather Service Station (Great Falls), it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station. In this instance, the anemometer at the weather service station is at 6.7 meters while the anemometer at the site was at 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where $V$ = wind speed at height $H$
$v$ = wind speed at a reference height $h$, and
$N$ = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there exists a time lag in weather between the site and the weather service station (6 to 24 hours depending on the distance and geographical features between the two locations).

Since the compilator reading periods are much longer than the weather time lag between the site and the weather service station, this effect can generally be ignored. When a reading period is of the same order of magnitude as the weather time lag, the resulting correlation value is not accurate. In this report, this circumstance applies to the reading period 8/31/81 to 9/1/.

To calculate the wind speed correlation factors between the site and the weather service station, the three-hourly average readings from the weather service station, corresponding to each compilator reading period, were extrapolated up to a sensor height of 10 meters. Then, the average speed at the site was divided by the extrapolated average speed at the weather station to obtain the average correlation value for each reading period. To minimize averaging errors, separate running total were mainitained when calculating the average monitoring period correlation factor.

The final level of data analysis was projection of maximum, minimum and average amounts of wind which can reasonably be expected at the monitoring site over a ten-year period. In this process, the correlation factor is applied to 10 years of national weather station data to project wind speed and wind power density at the site. To project wind speed, three-hourly average speed data from the weather station was extrapolated to an elevation of 10 meters, multiplied by the monitoring period correlation factor, then averaged. For wind power density, each three-hourly average speed was first cubed, then added into the running total used to calculate the average wind power density. Separate running totals of the three-hourly averages were maintained for both the monthly and yearly averages.

Wind power density is the most useful statistic to compare the energy potential of several sites or to estimate the appropriate size of a wind generator. Even so, it is usually the least used by wind developers. Wind power density is defined as:

$$P = (1/2) p K V^3$$

where P = wind power density
p = air density
V = wind speed
K = a proportionality constant used to resolve differences in units of the various equation terms

Note that air density p is defined as: p = A/(RT)

where A = atmospheric pressure
R = ideal gas constant, for air is 288.7 Joule/Kg degree Kelvin
T = absolute air temperature.

The final working version of this equation is:

$$P = \frac{A\ V\ (.01547)}{(5/9)(T-32) + 273.15}$$

where A = average air pressure in millibars
V = the average of the three-hourly MPH wind speed readings cubed
T = average temperature in degrees F.

The reason wind power density is better than wind speed as a basis for selecting a site and a machine for wind electric generation can be seen in the equation above. It shows that the power in the wind (which is what a wind electric generator absorbs and transmits) is proportional to the cube of the wind speed. Now, if wind power density is calculated from an average wind speed, which mixes all the instantaneous wind speeds above the average speed with all the instantaneous speeds below it on a linear scale, the result, when cubed, will be much lower than if each instantaneous wind speed had been cubed first and then all the cubed speeds averaged. The following example illustrates this fact: averaging these randomly-selected numbers (0,9,15,31,28,14,6,4,0) and cubing the result yields a value of 1680. Cubing each number and averaging the cubed values yields a value of 6541. Note the amount of error. The longer the string of averages used in projecting wind power density the greater the error in the wind power density becomes.

The above equation for wind power density also accounts for the difference in air density between the summer and winter months by its use of monthly average air temperature and pressure to calculate monthly wind power density. In addition, it accounts for the air density at the site as related to elevation above sea level (so long as the elevation at the site does not differ significantly from the elevation at the National Weather Service Station.)

The monthly and yearly maximum, minimum and average wind year's speed and percentage speed profiles were calculated in the same manner as the percentage speed profiles previously discussed except that the data summarized was a year of National Weather Service Station 3-hourly averages and that the summary periods are by the month and year.

The monthly and yearly average wind speed percentage profile is the most useful item in the report for estimating the actual ouput of a wind generator at the monitoring site. See the Data Use section for instructions.

## Data Use

First, refer to Appendix I and compare the average wind power density at your monitored site to the densities at other sites in the state. (Comparison of wind power densities provides the best picture of how one site's potential compares with others.)

Next, estimate the power output you might expect from a particular wind generator installed at your site. You will need the generator manufacturer's wind-speed-versus-power output graph, or "power characteristic curve' as it is sometimes called (Appendix II is such a curve for a Holec Windmatic model 14S wind generator), and the "Average Monthly and Yearly Wind Speed and Percentage Speed Profile" of your site. Follow the procedure in the example below to estimate yearly (or monthly) generator ouput. Then, to calculate a dollar value of the power that generator might generate under the conditions at your site, multiply the estimated generator output by the value of the electricity you would be displacing.

In the following example use the Power Characteristic Curve in Appendix II and the following annual wind speed percentage spectrum:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <38 | <40 | >40 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 5 | 9 | 4 | 5 | 12 | 10 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

The first step is to convert these annual percentage figures into the number of hours per year the wind blew in each bracket. Multiply the percent value from the percentage spectrum by the number of hours in a year, (365 X 24 = 8,760 hours in a year). The wind blew .41 X 8,760 = 3,591.6 hours during the year at speeds in the less-than-10-MPH bracket. For the second bracket, the wind blew .05 X 8,760 = 438 hours at speeds between 10 and 10.99 MPH. This process can be continued for each bracket of the spectrum. The final result will look like:

PERCENT OF WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | ... | <34 | ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,591.6 | 438 | 788.4 | 350.4 | 438 | 1051.2 | 876 | 438 | 262.8 | 175.2 | 87.6 | ... | 0 | ... |

NUMBER OF HOURS THE WIND BLEW IN EACH PERCENTAGE BRACKET

The next step is to assign a MPH value to the middle of each velocity bracket and then use the Power Characteristic Curve to find the generator's power output for each associated midpoint speed. The midpoint of each velocity bracket has been rounded to the nearest MPH for convenience below.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 | 35 | 37 | 39 | 41 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 2 | 4 | 7 | 11 | 17 | 21 | 27 | 33 | 39 | 45 | 50 | 55 | 59 | 60 | 62 | 60 |

GENERATOR OUTPUT (KW) FROM POWER CHARACTERISTIC CURVE

To do the final step, multiply the number of hours in each bracket by the generator output and add all of the ouputs together to obtain the total generator output for the period, which, in this example, is one year.

MIDPOINT OF VELOCITY BRACKETS (MPH)

| 5 | 11 | 12 | 13 | 14 | 15 | 17 | 19 | 21 | 23 | 25 | 27 | 29 | 31 | 33 ... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 701 | 1752 | 7358 | 9636 | 7446 | 5519 | 4730 | 2891 | 3416 | 3942 | 4380 | 0 ... |

PERIOD GENERATOR OUTPUT (KWH) PER BRACKET

In this example, the generator output for the total period (one year) is 51,771 KWh. To find the value of the electricity which would theoretically be displaced by this generator at a site with this wind speed profile, multiply the value of the electricity by the total production. In this example we will use $.0625/KWh for the unit value of displaced electricity; therefore, the total value of the displaced electricity would be $3,235.69 per year.

However, many factors other than the cost of the generator and the value of displaced electricity must be considered to make a realistic evaluation of the economics of wind electric generation at your site--factors such as: the one-time costs of site preparation (land rental, road improvement, power line installation and connection), legal fees, charges for the foundation, freight charges, fees for inspection and system checkout, and the continuous expenses of insurance, operation and maintenance. The following breakdown gives a broad guideline for the cost of a larges scale wind development:

| | |
|---|---|
| Generator and Blade Assembly - | 57% |
| Tower and Site Access - | 11% |
| Foundation/Site Preparation - | 9% |
| Operations/Maintenance - | 9% |
| Assembly/Checkout - | 8% |
| Other - | 4% |
| Equipment Transportation - | 2% |

Source: from publication SERI/SP-732-728 pulblished by the Solar Energy Research Institute, October 1980.

Not all of these costs will apply in the same percentages to every installation, but the likelihood is always a good that other costs will occur in their place.

As a rule of thumb, a wind site that has a wind power density of over 200 watts per square meter and has a minimum average wind speed of 12 MPH for at least six months per year should considered for wind development. The final decision to develop your wind potential is an investment decision which deserves the same degree of careful analysis as you give any other development investment. Appendix III is a suggested wind electric generation development guide.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this week's example, 82% of the time the wind blew between 0 and 10 MPH, 6% of the time it blew between 10 and 11 MPH, 3% of the time between 11 and 12 MPH, 4% between 12 and 13 MPH, etc.

On the summary sheet titled, "Average Wind Power Density in Watts/M2" the last column gives the reading period and monitoring period average wind power density at the site. The average wind speed in mph is also shown.

The "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary is the statistical core of the report. It gives the correlation factors which compare the wind speeds at the monitoring site to those at the nearest NCC weather station. The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors", which shows the percent of correlation factors that fall into each bracket of the spectrum. The smoother the distribution, the more valid the correlation factors. There is no percentage spectrum, or minimum or maximum correlation factor for each reading period since only one correlation factor is generated given the nature of the data stored by a compilator. Since only one value is generated a spectrum distribution and minimum or maximum values have no meaning.

These correlation factors express the wind speed at the site as a percent of the wind speed recorded at the same time at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

Next, there are three sheets titled, "Monthly and Yearly Average Wind Power Density In Watts/Sq. Meter". The first one gives the average ("Mean Wind Year"), the next gives the lowest ("Minimum Wind Year") and the third gives the highest ("Maximum Wind Year") wind power density likely to occur at the site over a ten-year period. If a site owner is considering installing a wind generator, these sheets give an idea of how the generator output can be expected to vary as the wind power density varies from year to year.

Finally, there are three summaries titled, "Monthly and Yearly Average Wind Speed (MPH) and Percentage Speed Profile." Like the three preceeding summaries, these also deal with the mean, minimum and maximum wind years. But while the preceeding summaries estimate wind power density, these estimate wind speed averages--the mean, minimum and maximum monthly and yearly average wind speeds likely to occur at the site--and arrange them by percentage into velocity brackets. To interpret the velocity brackets, see the description above of the "Wind Speed Summary and Percentage Speed Profile".

The Data Use section of this report contains directions for using these summaries to estimate the monthly and yearly output of a wind generator operating at a height of 10 meters (33 feet) under the same conditions as those found at the site. Since most generator towers are taller than 10 meters and since wind speed and, therefore, wind power increase as the height above the surface increases, it follows that an estimate based on this data and using this method will be a conservative one.

## WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPEED PROFILE

LOCATION: POWER TOWER HEIGHT: 10 METERS
YEAR: 1981

| PERIOD | AVERAGE WIND SPEED | PERCENT OF WIND IN VELOCITY BRACKETS <10 | <12 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/20- 7/ 2 | 9.3 | 62 | 12 | 8 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/ 2- 7/23 | 8.5 | 70 | 10 | 6 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7/23- 8/ 3 | 8.0 | 74 | 9 | 5 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 8/ 3- 8/13 | 6.3 | 86 | 6 | 4 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8/13- 8/23 | 6.7 | 82 | 9 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 8/31- 9/ 1 | 8.3 | 68 | 11 | 7 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 |
| 9/12- 9/20 | 7.8 | 75 | 10 | 6 | 4 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/20-10/ 4 | 10.4 | 55 | 12 | 8 | 6 | 5 | 4 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 10/14-10/18 | 12.4 | 36 | 17 | 14 | 9 | 7 | 6 | 4 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| PERIOD AVG: | 8.5 | 69 | 10 | 7 | 4 | 3 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |

```
                    AVERAGE WIND POWER DENSITY IN WATTS/M2


LOCATION:  POWER                TOWER HEIGHT= 10 METERS
YEAR:  1981

  PERIOD  AVG SPEED (MPH) AVG PRESSURE (MBS)  AVG TEMPERATURE (F)  AVG WIND POWER DENSITY
-----------------------------------------------------------------------------------------
 6/20- 7/ 2    9.3              887.1                58.1                    91
 7/ 2- 7/23    8.5              890.2                66.5                    87
 7/23- 8/ 3    8.0              890.2                66.5                    63
 8/ 3- 8/13    6.3              890.8                69.8                    26
 8/13- 8/23    6.7              890.8                69.8                    42
 8/31- 9/ 1    8.3              890.8                69.8                    74
 9/12- 9/20    7.8              890.8                59.8                    71
 9/20-10/ 4   10.4              890.8                59.8                   130
10/14-10/18   12.4              888.1                45.3                   167
-----------------------------------------------------------------------------------------
  AVERAGES:    8.5              890.0                62.8                    81
```

MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

SITE LOCATION: POWER NCC STATION LOCATION: GREAT FALLS
YEAR: 1981
DNRC WIND TOWER HEIGHT: 10.0 METERS
NCC WIND TOWER HEIGHT: 6.7 METERS

(1.0=PERFECT SITE/WEATHER STATION CORRELATION)

| | <-CORRELATION FACTORS-> | | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PERIOD | MEAN | MINIMUM | MAXIMUM | <0.3 | <0.6 | <0.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | 3.0 |
| 6/20- 7/ 2 | 0.93 | | | | | | | | | | | | | |
| 7/ 2- 7/23 | 0.90 | | | | | | | | | | | | | |
| 7/23- 8/ 3 | 0.89 | | | | | | | | | | | | | |
| 8/ 3- 8/13 | 0.90 | | | | | | | | | | | | | |
| 8/13- 8/23 | 0.90 | | | | | | | | | | | | | |
| 8/31- 9/ 1 | 0.69 | | | | | | | | | | | | | |
| 9/12- 9/20 | 0.87 | | | | | | | | | | | | | |
| 9/20- 10/ 4 | 0.98 | | | | | | | | | | | | | |
| 10/14- 10/18 | 1.00 | | | | | | | | | | | | | |
| MONITORING PERIOD | 0.92 | 0.69 | 1.00 | 0 | 0 | 67 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

```
           MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                                   MEAN WIND YEAR

SITE LOCATION: POWER                  NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                    PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED   <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN   16.6     23   3   5   4   2   8   8  10  11   4   7   7   3   2   2   1   0   0   0

 FEB   13.2     30   5   9   8   6   9  11   8   6   1   4   2   0   0   0   0   0   0   0

 MAR   14.1     23   6  12   7   6   7  14  10   5   3   2   2   2   0   0   0   0   0   0

 APR   13.5     34   6  10   5   8   4  10   8   3   3   1   2   3   0   0   2   0   0   0

 MAY   12.5     36   6  14   4   8   6  10   4   4   2   2   2   2   0   0   0   0   0   0

 JUN   13.1     36   7   8   7   5   8   8   6   6   2   2   3   2   0   0   0   0   0   0

 JUL   10.6     58   5   9   6   3   4   6   3   3   1   0   1   0   0   1   0   0   0   0

 AUG   10.8     49   9   9   7   6   4   5   4   2   0   1   1   2   0   0   0   0   0   0

 SEP   11.4     46   8   8   7   5   4   6   6   3   2   2   1   0   0   0   0   0   0   0

 OCT   14.2     31   4   8   4   7   6  12   8   4   4   3   4   3   0   1   0   0   0   0

 NOV   13.2     36   4  10   6   7   3   8   6   4   6   3   3   2   0   0   1   0   0   0

 DEC   14.9     32   3   4   5   5   4   9   7   8   5   4   5   5   0   1   0   0   1   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973  13.2     36   6   9   6   6   5   9   7   5   3   2   3   2   0   1   0   0   0   0
```

```
        MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                              MINIMUM WIND YEAR

SITE LOCATION: POWER              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

       AVG                    PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
-------------------------------------------------------------------------------------------

 JAN   12.1      42   5   2   3   7   4   9   7   5   5   5   4   2   0   0   0   0   0   0

 FEB   13.2      44   4   5   2   4   4   8   6   7   6   3   1   4   0   1   0   0   0   0

 MAR   12.6      44   4   4   3   6   5  10   9   4   3   4   2   0   0   1   0   0   0   0

 APR   12.1      31  14  12   6   6   3   8   8   4   3   2   1   1   0   0   0   0   0   0

 MAY    9.9      57  10  10   6   5   1   3   3   3   1   1   0   0   0   0   0   0   0   0

 JUN   10.4      56   8   5   5   4   4   6   5   5   0   0   0   0   0   0   0   0   0   0

 JUL    8.7      70   8   5   3   3   3   4   2   1   1   0   0   0   0   0   0   0   0   0

 AUG    9.1      65   9   6   5   3   2   3   4   1   0   1   0   0   0   0   0   0   0   0

 SEP    9.4      64   7   9   2   4   3   5   2   2   1   1   0   0   0   0   0   0   0   0

 OCT    9.8      56   7   9   4   3   3   6   6   3   3   0   0   0   0   0   0   0   0   0

 NOV   11.1      43   7  11   6   7   8   9   4   4   1   0   0   0   0   0   0   0   0   0

 DEC   16.3      23   3   8   7   7   3   9   7   9   6   3   5   5   0   2   3   0   1   0

-------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979  11.2      50   7   7   4   5   3   7   5   4   3   2   1   1   0   0   0   0   0   1
```

```
         MONTHLY & YEARLY AVG WIND SPD (MPH) AND PERCENTAGE SPEED PROFILE
                              MAXIMUM WIND YEAR


SITE LOCATION: POWER                NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

        AVG                       PERCENT OF WIND IN VELOCITY BRACKETS
MONTH  SPEED    <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 <40 >40
--------------------------------------------------------------------------------------------

 JAN    18.0     22   3   5   4   5   3  11   7   9   4   4   7   5   1   3   5   0   1   3

 FEB    18.4     11   2   6   4   6   5  13  12  13   6   6   7   4   1   2   1   0   0   0

 MAR    15.9     28   4   8   1   7   5  11   7   7   4   4   2   5   1   2   0   0   1   2

 APR    12.2     40   3  15   5   7   6   7   6   3   3   2   2   0   0   0   0   0   0   0

 MAY    12.9     38   4  10   2   8   6  12   7   3   3   2   3   2   0   0   0   0   0   0

 JUN    11.9     43   8  12   3   5   5  11   3   3   3   2   0   1   0   0   0   0   0   0

 JUL    10.7     54   3  12   4   6   3   8   3   2   2   1   2   1   0   0   0   0   0   0

 AUG     9.4     61   5  11   4   8   4   4   2   1   0   0   0   0   0   0   0   0   0   0

 SEP     9.9     60   5   8   4   5   3   4   4   3   1   2   0   0   0   0   0   0   0   0

 OCT    12.3     41   5   8   5   7   7   9   7   2   2   4   2   1   0   0   0   0   0   0

 NOV    14.2     31   4   9   3   6   4  13   8   8   4   3   3   4   0   0   0   0   0   0

 DEC    18.1     15   4   6   6   5   3  15   7   7   7   5   4   7   2   3   4   0   1   0

--------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974   13.6     37   4   9   4   6   4  10   6   5   3   3   3   3   0   1   1   0   0   0
```

```
          MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                                  MEAN WIND YEAR

SITE LOCATION: POWER              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/73
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE       AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)              (MBS)                (F)                   (W/M2)
------------------------------------------------------------------------------------------
 JAN        16.6              887.7               24.9                    402

 FEB        13.2              887.3               29.6                    186

 MAR        14.1              884.5               39.5                    210

 APR        13.5              886.9               40.2                    230

 MAY        12.5              886.3               59.4                    168

 JUN        13.1              887.5               63.6                    198

 JUL        10.6              889.5               71.4                    108

 AUG        10.8              889.0               71.2                    111

 SEP        11.4              890.0               58.2                    127

 OCT        14.2              889.5               47.2                    254

 NOV        13.2              888.7               25.2                    243

 DEC        14.9              887.2               28.9                    342

------------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1973       13.2                                                          213
```

```
        MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MINIMUM WIND YEAR


SITE LOCATION: POWER              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/79
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
           (MPH)             (MBS)                 (F)                  (W/M2)
-----------------------------------------------------------------------------------------
 JAN        12.1             887.7                 6.5                  227

 FEB        13.2             887.1                18.8                  258

 MAR        12.6             884.5                34.7                  209

 APR        12.1             886.8                40.7                  152

 MAY         9.9             886.4                51.5                  100

 JUN        10.4             887.4                62.9                  113

 JUL         8.7             889.5                69.0                   61

 AUG         9.1             889.2                68.5                   67

 SEP         9.4             890.2                62.9                   74

 OCT         9.8             889.3                49.4                   97

 NOV        11.1             888.6                33.4                  110

 DEC        16.3             886.6                34.6                  399

-----------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1979       11.2                                                        153
```

```
        MONTHLY AND YEARLY AVERAGE WIND POWER DENSITY IN WATTS/SQ. METER
                              MAXIMUM WIND YEAR

SITE LOCATION: POWER              NCC WEATHER STATION LOCATION: GREAT FALLS
STARTING TIME FOR PROJECTED DATA:  200 HOURS ON  1/ 1/74
AVERAGE SITE/WEATHER STATION CORRELATION FACTOR: 0.92
PROJECTED WIND SPDS AT 10 METER ELEVATION

MONTH  AVG WIND SPEED     AVG PRESSURE        AVG TEMPERATURE     AVG WIND POWER DENSITY
            (MPH)             (MBS)                 (F)                  (W/M2)
-----------------------------------------------------------------------------------------
 JAN        18.0              883.8                19.8                  613

 FEB        18.4              885.2                33.8                  436

 MAR        15.9              882.2                33.3                  419

 APR        12.2              886.2                47.1                  152

 MAY        12.9              885.5                49.5                  196

 JUN        11.9              886.2                66.9                  137

 JUL        10.7              888.9                72.9                  114

 AUG         9.4              890.6                62.9                   60

 SEP         9.9              892.3                54.8                  101

 OCT        12.3              891.6                51.4                  176

 NOV        14.2              888.3                38.7                  255

 DEC        18.1              885.5                32.5                  493

-----------------------------------------------------------------------------------------
YEARLY AVERAGE:
 1974       13.6                                                         258
```

# APPENDIX I

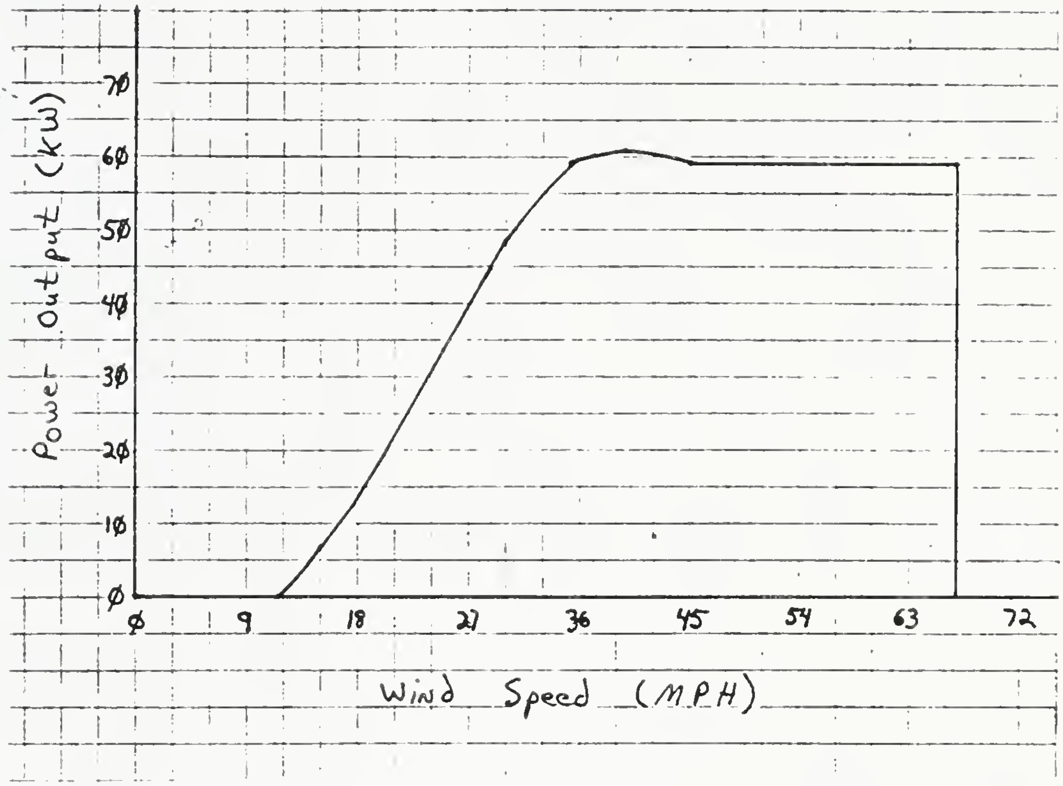
## Average Yearly Wind Speed & Wind Power Density at 10 Meter Elevation

| Station Name | average yearly speed (MPH) | average yearly wind power density (Watts/Sq. Meter) |
|---|---|---|
| Billings Logan International Airport | 12.3 | 156 |
| Bozeman Airport | 7.8 | 63 |
| Butte-Silver Bow County Airport | 7.6 | 70 |
| Cut Bank Airport | 13.7 | 284 |
| Dillon; Beaverhead County Airport | 10.1 | 103 |
| Glasgow International Airport | 12.1 | 174 |
| Great Falls International Airport | 12.8 | 217 |
| Havre City-County Airport | 11.4 | 161 |
| Lewistown Airport | 11.0 | 137 |
| Livingston Airport | 14.5 | 403 |
| Miles City Airport | 10.1 | 108 |
| Superior Airport | 4.9 | 13 |
| Whitehall CAA | 13.4 | 340 |

*Data from Wind Resource Atlas: Volume 1 - Northwest Region by Battelle Pacific Northwest Laboratory, PNL-3195 WERA-1 UC-60, April 1980, p. 76.

# APPENDIX II

Power Characteristic Curve For a Holec Windmatic model 14S Wind Generator
Wind Speed Versus Generator KWh Output



## APPENDIX III

## WIND SITE DEVELOPMENT GUIDE

Prepared by Gunderson Consulting Service
525 E. Davis, Bozeman, MT Tel: 406/586-3502

I. Preliminary Feasibility Study--Cost: $0

1. Obtain local weather data--monthly & yearly average wind speeds.
2. Review your electric bills; figure your maximum, minimum and average monthly electric loads. The longer the period you review, the better.
3. Determine what conservation measures could reduce your electric load.
4. Read all the wind generation literature you can find.
5. Look your property over and pick the most likely potential wind sites. As a rule of thumb, a site that has a wind power density of over 200 watts per square meter and has a MINIMUM average wind speed of 12 MPH during at least six months a year can be considered for development.
6. Start to think about how much of your electric load you can eliminate by conservation and how much you want to generate with wind power. Decide how much of your time you can devote to developing & using the wind resource on your property. Try to imagine how a wind installation might affect your and your neighbors' property.
7. Set a ceiling in dollars on the amount you are willing to invest in wind generation.
8. Contact your utility company and obtain their policies and procedures for connecting a wind generator to their transmission system. Find out how much they will pay you for electricity you generate.
9. Cultivate the habit of keeping detailed records and files.

II. Final Feasibility Study--Cost: $0 - $3,000

1. As a rule of thumb, a wind site is a good prospect for development if it has a wind power density of over 200 watts per square meter and has an average wind speed of no less than 12 MPH for at least six months per year. To decide whether or not your wind resource warrants investment, you may need a wind resource study to measure the wind speed and direction at your site. This will depend on two factors:
   a) the availability and quality of existing wind speed and direction data from a nearby source, such as a National Weather Service Station, and
   b) the total amount of your proposed investment.
      i) $0 - $5,000 & no financing. Some generator dealers will perform a 3-month wind speed study at a client's site; others rely on existing data from a nearby site such as a National Weather Service station. Cost: $0
      ii) $5,000 - $10,000 with partial financing. The lending institution may want to see the results of a 6-month wind study before approving a loan. You, too, should want a study of your wind resource before borrowing money. Some generator dealers perform such studies for their clients; private consultants do wind resource studies without consideration of a particular wind generator. Cost $0 - $2,500.
      iii) More than $10,000 with major financing. An investment of this size requires an independent, long-term wind resource study. Cost: around $ 3,000 depending on term and number of sites.
2. Contact one or more wind generator dealers, the State energy office and a private consultant; tell them your investment ceiling and ask for their estimate of the cost of various sized wind generators and the quantity of electricity those generators could be expected to produce under the

wind and temperature regime at your site. Get all the wind generator brochures, data sheets and specifications you possibly can.

3. Look over the information you have collected, and, if you still want to develop your wind resource, select the system which falls below your investment ceiling, leaves room for all the other costs and seems most likely to produce the amount of electricity you think you should get under the conditions at your site.
4. Contact a dealer of the machine you have selected. If the dealer knows you are a serious customer, they should be willing to furnish you the following information:
   - a) An estimate of the monthly minimum, maximum and average electric output you could expect from the generator under conditions described by the data from your site.
   - b) An estimate of all installation, connection and maintenance costs, and an economic analysis showing the assumptions made and the estimated payback period for this generator under your conditions.
   - c) Complete warranty information.
   - d) Complete information for utility/home electric interface connection.
   - e) Maintenance schedules and their costs.
   - f) A sample of the dealer's contract form or forms to cover installation, electrical interface and system startup.
   - g) A list of customers who have used the generator model you are looking at for at least 1 year in a climate similiar to your site.
   - h) A description of the dealer's experience with the particular generator. A short history of the manufacturer is also nice to have.

No dealer will be willing to furnish all this information until they know you are seriously interested in a generator. But the dealer's first response to you is a good indication of their reliability and of the the quality of their product. The more contact you have with the dealer, the more of this information you will receive. If information seems too hard to get, you should consider finding another dealer. You should expect to have all your questions answered to your satisfaction.

III. Installation, Operation & Maintenance.

At this point, ask yourself if you still want to invest in your wind site. If you do not feel satisfied about your wind prospect at this point, you would be better off to write off all your work to date (and money as well, if you've had a wind resource study) than to spend $10 - 100 thousand more for a wind machine that does not generate the electricity your investment depends on. Remember that you can write off a business loss just as easily as you can take a tax credit for a renewable energy investment. And finally, remind yourself that no generator can improve the wind at your site.

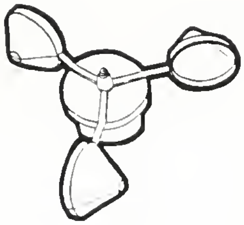
If you decide to proceed with your investment plans, the first step is to follow through on the conservation measures you identified at the beginning of your feasibility study.

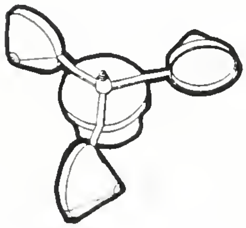
Then, here, in general, are the steps to getting those first kilowatts flowing:

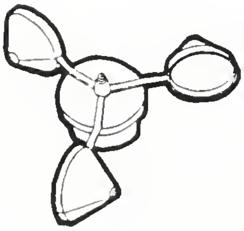
1) If you plan to intertie with the utility system, negotiate a buy-back contract with your utility company. You will have to have their approval of the electrical interconnect your dealer plans to use and you may have to meet their insurance requirements.
2) From your city/county planning and zoning departments obtain whatever installation permits or licenses they require.
3) Get your insurance agent's advice on what kinds of insurance your installation will need and order it.

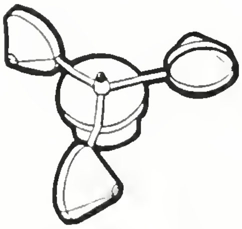
4 ) Get together with your dealer and prepare a final economic analysis. Considering ALL costs, calculate the payback period. If the total cost and and the payback period still suit you, then you know your investment is as solid as you can make it.
5 ) Consider having legal review of the contract your dealer offers, then negotiate it with your dealer. This is also a good time to negotiate a maintenance contract.
6 ) After your generator is installed and operating, have your dealer or an independent consultant monitor the wind speed at your generator site for 3-6 months so you can compare the wind power potential during the period with the output from your generator during the same period to determine whether your generator is performing according to your expectations and the manufacturer's specifications.
7 ) Make sure that the maintenance schedule is followed and repairs are made whenever they are needed.

1/8/84









# Survey of Wind Power
# at
# The Marcel Solum Place, Rudyard, MT

September 10, 1980 - December 14, 1980

FOR
MONTANA DEPARTMENT OF
NATURAL RESOURCES AND CONSERVATION

Renewable Alternate Energy Program
Grant # 82-1016

Gunderson Consulting Service
525 East Davis St. • Bozeman, MT 59715
(406) 586-3502

## Description of Equipment

The wind data in this report was gathered and recorded by DNRC's wind monitoring system #DSR-3 at the Marcel Solum place near Rudyard, Montana from September 10, 1980 to December 14, 1980.

Natural Power Inc., New Boston, New Hampshire, manufactured the recorder and sensor used in the system which gathered this data. The system included a dual-channel strip chart recorder housed in a plastic case, a 4-pole cup anemometer, a wind direction sensor, a 12-volt wet cell automobile battery, and all the cable needed to connect the sensor to the recorder, the recorder to the battery and the entire system to a grounding stake. Completing the system were an instrument shelter and a 10-meter tower with mounting bracket, guy wires and stakes.

The wind direction sensor failed to operate during the period.

The operating specifications for the anemometer are:
Wind velocity range: 3- 150 MPH
Temperature range -60 to 200 degrees F.

The operating specifications for the strip chart recorder are:
Temperature range: 32 to 160 degrees F.
Recorder meter: + or - 1%
Recorder chart speed: + or - 5%
Response time: 5 seconds to full scale

The the strip chart recorder records a wind speed reading every two seconds by making a mark on the strip chart. To make the mark, an impact bar strikes the top side of the meter needle, which then touches pressure- sensitive paper (a "strip chart") moving slowly beneath the needle. These dots accumulate on the moving paper forming a graph of the wind speed.

The tower was a 10-meter Radio Shack telescoping TV antenna mast made of galvanized steel and guyed by eight cables in a 25' radius. It is rated to withstand winds up to 150 MPH.

The instrument shelter, made of wood and insulated with styrofoam, was located at the base of the tower to house the recorder and battery in side-by-side compartments. The system was grounded by a wire from the recorder to a four foot galvanized stake driven into the ground next to the shelter.

## Monitoring Method

On September 10, 1980, under contract with DNRC, Gunderson Consulting installed DNRC's wind monitoring system #DSA-3 at the Marcel Solum farm southwest of Rudyard, Montana (mailing address: Box 85, Rudyard, 59540). Between the date of installation and December 16, 1980, Marcel charged the batteries and changed the rolls of strip chart paper as they were filled. The anemometer and the strip chart recorder worked according to specifications during the monitoring period but the wind direction sensor failed to send any signals to the recorder. In June 1982, DNRC contracted with Gunderson Consulting to analyze and summarize the data on the strip charts.

To locate the monitoring site, drive south from Rudyard on State 432 eleven miles to mile marker 36. Turn west for two miles, south for one mile and west for two more miles to the Solum farm.

## Description the Data Analysis Procedure

Analysis of the strip chart data was done on a computer system composed of the following items: a Southwest Technical Products Corporation model CT-82 intelligent terminal, model 69A central processing unit, two model MF-69 dual-sided single density disk drives, an Integral Data System, Inc. model 440 dot-matrix impact printer and a Houston Instrument HI PAD digitizing pad with a one-button cursor.

The strip charts were digitized and stored on 5.25 inch floppy disks. In this process, an operator uses the cursor and digitizer pad to trace six-inch segments (referred to as "plots") of the wind-speed-versus-time curve on the strip chart (105 segments per strip chart). This sends a stream of XY coordinates to the computer, which receives and stores them with an accuracy of + or - .015 of an inch. For this study, the coordinates were stored on disk with three decimal places.

After the strip charts were digitized the data was averaged into hourly wind speeds as follows: the digitized wind speed coordinates were corrected for the nonlinear response of the strip chart recorder; the strip chart time coordinates were corrected for variations in the operating speed of the recorder over the period of time it took to fill the strip chart; the resulting corrected hourly speeds were averaged.

At the next level of analysis, the hourly wind speed data was summarized into daily, weekly and monthly summaries. To do this, the computer read the houly wind speed elements one day at a time and averaged them into daily, weekly and monthly average wind speed profiles. It carried individual running totals for each summary period to minimize averaging error.

Also, a wind speed percentage spectrum was calculated, as follows: the computer counted hourly wind speeds, then sorted them into speed brackets, simultaneously keeping a count of elements sorted into each bracket for each time summary period. At the end of the time summary period, the number of speed elements sorted into each speed bracket was divided by the total count of elements for the summary period, which produced the percent of time the wind blew in each speed bracket during the period. The wind speed percentage brackets were sized to fit the performance of most wind generators, i.e., startup wind speeds between 10 and 14 MPH, highly variable production up to 30 MPH and generally flat performance at speeds greater than 30 MPH.

Next, the computer calculated weekly and monthly wind power density values by averaging hourly wind speed cubed values for each summary period with the same kind of routine it used to calculate the average wind speeds. The process of calculating wind power density for each summary period will be described later in this report.

To correlate data from a monitoring site with data from the nearest National Weather Service Station, it must first be determined if any difference exists between the height of the anemometer at the site and the height of the one at the weather service station . In this instance, the anemometer at the nearest station (Havre) is at 6.1 meters while the anemometer at Rudyard was 10 meters. This difference was adjusted by the standard method used in the industry, called the "1/7 power law":

$$\frac{V}{v} = \left[\frac{H}{h}\right]^{N}$$

where V = wind speed at height H
v = wind speed at a reference height h, and
N = 1/2 for 0 to 5 MPH winds
= 1/5 for 5 to 35 MPH winds
= 1/7 for winds greater than 35 MPH.

In addition to the variation in tower height, there always exists a time lag in weather between a site and its nearest weather service station. To accomodate this effect, the correlations for each three-hour period were averaged together to obtain a daily correlation factor. From these daily correlation factors, weekly, monthly and period correlation averages were calculated. Likewise, the correlation factor percentage spectrum and the mean, maximum and minimum correlation factors were selected from the daily average correlation factors. This technique averages out the lead/lag weather variations between two distant locations.

To calculate a wind speed correlation factor, three hours of site data were averaged together to correspond to the three-hourly average readings from the weather service station. The weather service reading was extrapolated up to the Rudyard sensor height of 10 meters. Finally the site three-hourly average speed was divided by the adjusted weather service station reading to obtain a three-hourly average correlation value. Eight three-hourly average correlation factors were averaged to produce a daily average correlation. Daily average correlation factors were then averaged by the week, month and period to produce average correlation factors. The mean, maximum and minimum correlation factors were selected from the daily average correlation factors.

We found the correlation factors between the Rudyard data and the Havre weather station data to be invalid--they do not fall into the normal distribution which characterizes a valid correlation; also, the mean and maximum correlation factors are too large to be believed.

We conjecture that this lack of correlation between Rudyard and Havre is because the two towns lie in different wind patterns, even though only 37 miles separate them. Havre lies just beyond the northwestern corner of the Bear Paw mountains while Rudyard lies some distance from their western front. Perhaps these mountains divide the weather as it approaches from the north and northwest.

Since there is no valid correlation between Rudyard and its nearest weather service station, we couldn't project yearly average wind speed and power density for Rudyard. It is likely that a valid correlation exists between Rudyard and some other weather station, perhaps Glasgow or Great Falls or a Canadian station.

This is the second location where we have found no valid correlation between the Havre weather station and a monitoring site. Chinook is the other. This double lack of correlation is especially puzzling because Havre lies only about 30 miles each way on a straight line between Rudyard and Chinook. Perhaps it is a weather phenomenon; or perhaps the Havre data is unreliable for the time period in question.

## HOW TO UNDERSTAND THIS DATA

The first data sheet is the "Wind Speed Summary (in MPH) & Percentage Speed Profile". This summary sheet gives the wind speed recorded by the monitoring system while it was at the site. The "WKLY AVG SPD" column gives the average wind speed for each week and month, and the wind speed percentage spectrum gives the percent of time during that week the wind was blowing in a particular wind speed bracket. For example, consider the following spectrum:

PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS

| <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 6 | 3 | 4 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

In this example, the wind blew less than 10 MPH 82% of the time, between 10 and 11 MPH 6% of the time, between 11 and 12 MPH 3% of the time, between 12 and 13 MPH 4% of the time, etc.

***********

Next is the "Weekly and Monthly Average Wind Power Density" sheet. This sheet contains the weekly and monthly average wind speed in MPH and wind power density in Watts per square meter for the monitoring period. The average monthly average air pressure and temperature are also listed.

***********

Next is the "Mean, Minimum and Maximum Correlation Factors and Frequency Percentage Spectrum" summary. It gives the correlation factors which compare the wind speeds at the monitoring site (Rudyard) to those at the nearest NCC weather station (Havre). The right half of the table is a "Frequency Percentage Spectrum of Correlation Factors", which shows the percent of correlation factors that fall into each bracket of the spectrum. Correlation factors express the wind speed at the monitoring site as a percent of the wind speed at the NCC weather station. For example: if the site wind speed is 5 mph and the NCC weather station wind speed is 10 mph, the correlation factor for that instant is 5/10 = .50, i.e., the site wind speed is 50% of the wind at the NCC station. If the wind speeds are reversed, the correlation factor is 10/5 = 2. If the wind speeds at the site and the NCC station are equal, the correlation factor is 1.00.

A smooth distribution of correlation factors across a spectrum indicates that the correlation is a valid one. The reader will note that these correlation factors fall in an erratic pattern, indicating that the correlatiion between Rudyard and Havre is not a valid one. That is to say, there is no reliable basis for comparing the wind at the Solum farm near Rudyard with the wind at the Havre weather station. As a result, we couldn't make long-term projections about wind patterns in Rudyard.

Local residents are probably aware of their unusual weather pattern and probably have an understanding of the causes. It is possible that the Rudyard data would correlate with data from some other weather service station, perhaps Great Falls, 100 miles southwest, or Glasgow, 140 miles east, or a Canadian station to the north.

* * *

The last ~~five~~ four pages are titled, "Wind Speed Summary (In MPH) and Percentage Spectrum.' These pages summarize the wind speed (in MPH) at the Rudyard site during the monitoring period on a daily, weekly and monthly basis. These pages have the same format as the weekly-monthly summary described above.

>

## WIND SPEED SUMMARY (IN MPH) & PERCENTAGE SPEED PROFILE

LOCATION: RUDYARD                TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 9/10/80

| WEEK ENDING | WKLY AVG SPD MPH / DAY | PERCENT OF WEEKLY WIND IN VELOCITY BRACKETS <10 | <11 | <12 | <13 | <14 | <16 | <18 | <20 | <22 | <24 | <26 | <28 | <30 | <32 | <34 | <36 | <38 | >38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/13 | *10.8 | 48 | 5 | 4 | 10 | 3 | 8 | 4 | 4 | 5 | 3 | 1 | 3 | 0 | 4 | 0 | 0 | 0 | 0 |
| 9/20 | 12.4 | 41 | 4 | 6 | 4 | 6 | 10 | 12 | 5 | 2 | 5 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9/27 | 9.1 | 62 | 3 | 8 | 1 | 4 | 7 | 7 | 6 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SEP | 11.2 | 50 | 4 | 6 | 4 | 4 | 8 | 7 | 5 | 4 | 3 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10/ 4 | 11.3 | 54 | 4 | 7 | 3 | 3 | 8 | 1 | 4 | 7 | 2 | 1 | 4 | 1 | 0 | 1 | 0 | 0 | 0 |
| 10/11 | 11.2 | 51 | 8 | 4 | 7 | 2 | 7 | 6 | 4 | 4 | 2 | 4 | 1 | 1 | 0 | 1 | 1 | 0 | 0 |
| 10/18 | 11.3 | 51 | 9 | 5 | 5 | 5 | 5 | 4 | 3 | 1 | 6 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| 10/25 | 8.9 | 77 | 5 | 3 | 1 | 0 | 1 | 1 | 2 | 2 | 3 | 2 | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| OCT | 9.7 | 65 | 7 | 4 | 4 | 2 | 4 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 0 | 1 | 0 | 0 | 0 |
| 11/ 1 | 7.3 | 82 | 7 | 2 | 1 | 1 | 3 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/ 8 | 12.0 | 52 | 7 | 7 | 5 | 2 | 4 | 4 | 4 | 3 | 1 | 2 | 4 | 2 | 2 | 1 | 1 | 0 | 0 |
| 11/15 | 5.9 | 86 | 5 | 3 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11/22 | 11.6 | 48 | 8 | 7 | 2 | 7 | 10 | 1 | 2 | 3 | 2 | 4 | 2 | 2 | 0 | 1 | 1 | 0 | 0 |
| 11/29 | 9.9 | 57 | 2 | 2 | 7 | 6 | 10 | 5 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 0 |
| NOV | 9.9 | 60 | 6 | 5 | 4 | 4 | 7 | 3 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| 12/ 6 | 9.4 | 68 | 4 | 4 | 5 | 5 | 5 | 3 | 2 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 12/13 | 9.0 | 68 | 0 | 5 | 1 | 1 | 4 | 6 | 2 | 4 | 4 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 12/15 | * 7.3 | 81 | 0 | 3 | 3 | 5 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 8.7 | 72 | 1 | 3 | 3 | 3 | 4 | 4 | 2 | 2 | 3 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

# WEEKLY AND MONTHLY AVERAGE WIND POWER DENSITY

LOCATION: RUDYARD TOWER HEIGHT: 10 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 9/10/80

| WEEK ENDING | AVG WIND SPEED (MPH) | AVG PRESSURE (MBS) | AVG TEMPERATURE (DEGREES F) | AVG WIND POWER DENSITY (WATTS/SQ. METER) |
|---|---|---|---|---|
| 9/13 | *10.8 | | | 190 |
| 9/20 | 12.4 | | | 170 |
| 9/27 | 9.1 | | | 83 |
| SEP | 11.2 | 922.7 | 57.5 | 162 |
| 10/ 4 | 11.3 | | | 173 |
| 10/11 | 11.2 | | | 156 |
| 10/18 | 11.3 | | | 160 |
| 10/25 | 8.9 | | | 135 |
| OCT | 9.7 | 926.4 | 46.4 | 121 |
| 11/ 1 | 7.3 | | | 45 |
| 11/ 8 | 12.0 | | | 225 |
| 11/15 | 5.9 | | | 23 |
| 11/22 | 11.6 | | | 209 |
| 11/29 | 9.9 | | | 145 |
| NOV | 9.9 | 925.1 | 35.9 | 147 |
| 12/ 6 | 9.4 | | | 108 |
| 12/13 | 9.0 | | | 136 |
| 12/15 | * 7.3 | | | 34 |
| DEC | 8.7 | 927.5 | 18.9 | 112 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

MEAN, MINIMUM AND MAXIMUM CORRELATION FACTORS AND FREQUENCY PERCENTAGE SPECTRUM

LOCATION: RUDYARD NCC WEATHER STATION LOCATION: HAVRE
DNRC TOWER HEIGHT: 10.0 METERS
NCC TOWER HEIGHT: 6.1 METERS
STARTING TIME: 1700 HOURS
STARTING DATE: 9/10/80

(1.0 = PERFECT SITE/WEATHER STATION CORRELATION)

| WEEK | <-CORRELATION FACTORS-> | | | FREQUENCY PERCENTAGE SPECTRUM OF C.F.'S | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENDING | MEAN | MINIMUM | MAXIMUM | <.3 | <.6 | <.9 | <1.2 | <1.5 | <1.8 | <2.1 | <2.4 | <2.7 | <3.0 | >3.0 |
| 9/13 | *2.26 | 0.97 | 4.07 | 0 | 0 | 0 | 25 | 25 | 0 | 0 | 0 | 25 | 0 | 25 |
| 9/20 | 1.38 | 0.90 | 2.58 | 0 | 0 | 14 | 43 | 14 | 0 | 14 | 0 | 14 | 0 | 0 |
| 9/27 | 1.39 | 1.00 | 1.85 | 0 | 0 | 0 | 43 | 29 | 0 | 29 | 0 | 0 | 0 | 0 |
| SEP | 1.57 | 0.90 | 4.07 | 0 | 0 | 5 | 38 | 24 | 0 | 19 | 0 | 10 | 0 | 5 |
| 10/ 4 | 1.47 | 0.85 | 1.98 | 0 | 0 | 14 | 29 | 14 | 0 | 43 | 0 | 0 | 0 | 0 |
| 10/11 | 1.45 | 0.84 | 2.47 | 0 | 0 | 14 | 43 | 14 | 0 | 0 | 0 | 29 | 0 | 0 |
| 10/18 | 1.66 | 0.75 | 3.12 | 0 | 0 | 29 | 0 | 14 | 14 | 14 | 14 | 0 | 0 | 14 |
| 10/25 | 1.54 | 0.82 | 2.68 | 0 | 0 | 14 | 43 | 0 | 14 | 0 | 14 | 14 | 0 | 0 |
| OCT | 1.45 | 0.75 | 3.12 | 0 | 0 | 23 | 29 | 10 | 10 | 10 | 6 | 10 | 0 | 3 |
| 11/ 1 | 1.12 | 0.76 | 1.77 | 0 | 0 | 29 | 43 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| 11/ 8 | 1.21 | 0.92 | 1.80 | 0 | 0 | 0 | 71 | 14 | 14 | 0 | 0 | 0 | 0 | 0 |
| 11/15 | 1.47 | 0.59 | 2.48 | 0 | 14 | 0 | 0 | 43 | 29 | 0 | 0 | 14 | 0 | 0 |
| 11/22 | 1.31 | 0.67 | 1.82 | 0 | 0 | 29 | 14 | 0 | 43 | 14 | 0 | 0 | 0 | 0 |
| 11/29 | 1.63 | 0.70 | 2.38 | 0 | 0 | 14 | 14 | 14 | 14 | 14 | 29 | 0 | 0 | 0 |
| NOV | 1.40 | 0.59 | 2.48 | 0 | 3 | 10 | 27 | 17 | 27 | 7 | 7 | 3 | 0 | 0 |
| 12/ 6 | 1.54 | 0.69 | 2.50 | 0 | 0 | 14 | 0 | 43 | 14 | 14 | 0 | 14 | 0 | 0 |
| 12/13 | 1.77 | 0.22 | 4.55 | 14 | 14 | 14 | 0 | 0 | 0 | 29 | 14 | 0 | 0 | 14 |
| 12/15 | *0.45 | 0.28 | 0.61 | 50 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEC | 1.49 | 0.22 | 4.55 | 13 | 7 | 20 | 0 | 20 | 0 | 20 | 7 | 7 | 0 | 7 |
| STUDY PERIOD | 1.47 | 0.22 | 4.55 | 2 | 2 | 14 | 26 | 16 | 11 | 12 | 5 | 7 | 0 | 3 |

NOTE: * INDICATES THAT A WEEKLY AVERAGE IS FOR FEWER THAN 7 DAYS.

```
           WIND SPEED SUMMARY (IN MPH) AND PERCENTAGE SPECTRUM


LOCATION:  RUDYARD                      TOWER HEIGHT:  10 METERS
STARTING TIME:  1700 HOURS
STARTING DATE:   9/10/80

                                              PERCENTAGE WIND SPEED PROFILE
  DATE    . AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
---------------------------------------------------------------------------------------------------
   10      * 5.4  7 HRS  100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   11       12.4          58   0   4   0   0   4   4   8   4   0   0   4   0  13   0   0   0   0
   12       10.8          63   4   0  13   0   4   4   4   0   4   0   4   0   0   0   0   0   0
   13       14.7           8  13   8  21   8  17   4   0  13   4   4   0   0   0   0   0   0   0

WKLY AVG=> 10.8           48   5   4  10   3   8   4   4   5   3   1   3   0   4   0   0   0   0

   14       10.8          46  13  13   0   4  13   4   0   0   0   4   4   0   0   0   0   0   0
   15       12.0          38   4   4   4   4  17  17   8   0   0   4   0   0   0   0   0   0   0
   16       12.8          50   0   4   4   0   4   4   4   4   4  13   8   0   0   0   0   0   0
   17       13.5          46   0  13   0   0   4   4   8   4  21   0   0   0   0   0   0   0   0
   18        9.3          58   0   4  17  17   4   0   0   0   0   0   0   0   0   0   0   0   0
   19       11.8          33   8   4   4  13  17  13   4   4   0   0   0   0   0   0   0   0   0
   20       16.2          17   0   0   0   4  13  42  13   4   8   0   0   0   0   0   0   0   0

WKLY AVG=> 12.4           41   4   6   4   6  10  12   5   2   5   3   2   0   0   0   0   0   0

   21       12.0          38   4  13   4   4   8   4  21   4   0   0   0   0   0   0   0   0   0
   22       11.2          46   4   8   0   4   8  13   8   4   4   0   0   0   0   0   0   0   0
   23       11.9          50   0   4   0   4  13  13   8   8   0   0   0   0   0   0   0   0   0
   24        8.9          63   4  13   0   0  13   8   0   0   0   0   0   0   0   0   0   0   0
   25        6.7          79   4   4   0   4   4   4   0   0   0   0   0   0   0   0   0   0   0
   26        6.0          83   4   4   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   27        7.0          75   0   8   4   0   4   4   4   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.1           62   3   8   1   4   7   7   6   2   1   0   0   0   0   0   0   0   0

   28       11.5          54   0   4   0   0   4   8   4   8   8   4   4   0   0   0   0   0   0
   29       14.6          46   4   4   0   0   4   0   4   8   8   4   8   8   0   0   0   0   0
   30       16.0          29   8   4   4   4  17   0   0  13   0   0  17   0   0   4   0   0   0
---------------------------------------------------------------------------------------------------
  SEP       11.2          50   4   6   4   4   8   7   5   4   3   2   2   0   1   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
     THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  2
STARTING TIME:  0000 HOURS
STARTING DATE:  10/ 1/80

                                            PERCENTAGE WIND SPEED PROFILE
  DATE    AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-------------------------------------------------------------------------------------------------

    1        11.2        42   4  21   8   8  17   0   0   0   0   0   0   0   0   0   0   0   0
    2         7.2        71   8   0   8   8   4   0   0   0   0   0   0   0   0   0   0   0   0
    3         6.7        92   0   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4        11.8        46   4   4   0   0  13   0  17  17   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 11.3         54   4   7   3   3   8   1   4   7   2   1   4   1   0   1   0   0   0

    5         8.6        67  13   4   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0
    6         9.2        63   8   0   4   0   8  13   4   0   0   0   0   0   0   0   0   0   0
    7        13.9        38   4  13   4   8   4   0   0   8   4  17   0   0   0   0   0   0   0
    8        14.6         4  17   8  17   0  25   8   8   0   8   4   0   0   0   0   0   0   0
    9        17.9        21   0   0   4   0   4  21  13  17   0   4   4   4   0   4   4   0   0
   10         7.1        83   8   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   11      * 6.8 23 HRS  83   9   0   9   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 11.2         51   8   4   7   2   7   6   4   4   2   4   1   1   0   1   1   0   0

   12         7.4        67  13   4   4   8   4   0   0   0   0   0   0   0   0   0   0   0   0
   13        16.7        21   8   4   4   8   8   4   4   4   8   4  13   8   0   0   0   0   0
   14        16.4        25   0   0   4   4   8  13   4   0  25  17   0   0   0   0   0   0   0
   15        15.1        13   4  13   8  13  13  13  13   0   8   0   4   0   0   0   0   0   0
   16         6.3       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   17         8.0        83   4   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   18         8.9        50  33   8   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=> 11.3         51   9   5   5   5   5   4   3   1   6   3   2   1   0   0   0   0   0

   19         7.8        79  13   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   20         6.1        92   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   21         8.3        79   8   0   0   0   4   0   4   4   0   0   0   0   0   0   0   0   0
   22        21.7        13   4   8   0   0   0   8   4   4  17  13   0   8   8  13   0   0   0
   23         5.7        92   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   24         5.2       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   25         7.8        83   0   4   0   0   0   0   4   4   4   0   0   0   0   0   0   0   0

WKLY  AVG=>  8.9         77   5   3   1   0   1   1   2   2   3   2   0   1   1   2   0   0   0

   26         9.2        75  17   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   27         4.1       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   28         6.9       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   29        12.9        38  17   0   4   4  13   4   8   4   0   8   0   0   0   0   0   0   0
   30         5.1       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   31         4.8       100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
-------------------------------------------------------------------------------------------------
  OCT         9.7        65   7   4   4   2   4   3   3   2   2   2   1   1   0   1   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

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PAGE  3
STARTING TIME:  0000 HOURS
STARTING DATE:  11/ 1/80

                                              PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD     <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
-----------------------------------------------------------------------------------------------------
    1       8.2             63  13  13   0   0   8   4   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  7.3            62   7   2   1   1   3   1   1   1   0   1   0   0   0   0   0   0   0

    2      16.9             21  13   8   8   8   0   4   4   4   4   4   8   4   4   0   4   0   0
    3       8.5             71  13  17   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    4       8.8             71   0   0  13   0   0   4  13   0   0   0   0   0   0   0   0   0   0
    5       6.2             88  13   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
    6      13.4             46   4   8   8   0   8   4   0   8   0   4   4   4   0   0   0   0   0
    7      11.6             42   4   4   8   4   8  13   4   4   4   0   0   4   0   0   0   0   0
    8      18.6             29   0   8   0   0   8   4   8   4   0   4  17   0   8   8   0   0   0

WKLY  AVG=> 12.0            52   7   7   5   2   4   4   4   3   1   2   4   2   2   1   1   0   0

    9       9.5             58   4   0   8  13  13   4   0   0   0   0   0   0   0   0   0   0   0
   10       5.1            100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   11       8.7             50  29  21   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   12     * 5.6 23 HRS     100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   13       4.2            100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   14       3.8            100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   15       4.4             96   0   0   0   0   4   0   0   0   0   0   0   0   0   0   0   0   0

WKLY  AVG=>  5.9            86   5   3   1   2   2   1   0   0   0   0   0   0   0   0   0   0   0

   16       4.5            100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   17       9.0             50  13  17   0  13   4   4   0   0   0   0   0   0   0   0   0   0   0
   18       7.5             67   8   8   0  13   4   0   0   0   0   0   0   0   0   0   0   0   0
   19      14.3             29  21   4   8   0  13   4   4   0   0   4   4   0   0   8   0   0   0
   20       8.8             58   4   8   0  13  17   0   0   0   0   0   0   0   0   0   0   0   0
   21      22.0              0   4   0   0   4  21   0   8  13   4  13  13  17   0   0   4   0   0
   22      14.7             29   4   8   4   8  13   0   0   8  13  13   0   0   0   0   0   0   0

WKLY  AVG=> 11.6            48   8   7   2   7  10   1   2   3   2   4   2   2   0   1   1   0   0

   23       5.3             88   0   4   4   4   0   0   0   0   0   0   0   0   0   0   0   0   0
   24       7.2             75   0   4   4   4  13   0   0   0   0   0   0   0   0   0   0   0   0
   25      11.5             54   0   0   0   8   8   0   8   4   8   4   0   0   4   0   0   0   0
   26      11.9             25   4   4  21   8  21  17   0   0   0   0   0   0   0   0   0   0   0
   27       7.4             67   0   0   4   0  21   8   0   0   0   0   0   0   0   0   0   0   0
   28      15.3             21  13   0   4  13   4   8  13   8   0  13   0   4   0   0   0   0   0
   29      10.5             67   0   0   8   4   4   0   0   0   4   0   4   4   0   0   4   0   0

WKLY  AVG=>  9.9            57   2   2   7   6  10   5   3   2   2   2   1   1   1   0   1   0   0

   30      12.3             29   8  13   8   8  17   8   4   0   4   0   0   0   0   0   0   0   0
-----------------------------------------------------------------------------------------------------
  NOV       9.9             60   6   5   4   4   7   3   2   2   1   2   2   1   1   1   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
```

```
PAGE  4
STARTING TIME:  0000 HOURS
STARTING DATE:  12/ 1/80

                                          PERCENTAGE WIND SPEED PROFILE
 DATE     AVG WIND SPD  <10 <11 <12 <13 <14 <16 <18 <20 <22 <24 <26 <28 <30 <32 <34 <36 <38 >38
----------------------------------------------------------------------------------------------------

   1        17.2         25   4   4   0   4   8  13   8   0   8   4   4   8   8   0   0   0   0
   2         8.5         83   4   4   8   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   3         9.7         67   4   4   0  13  13   0   0   0   0   0   0   0   0   0   0   0   0
   4         7.8         75   0   0  17   8   0   0   0   0   0   0   0   0   0   0   0   0   0
   5         5.5        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   6         5.1         96   4   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0

WKLY AVG=>  9.4          68   4   4   5   5   5   3   2   0   2   1   1   1   1   0   0   0   0

   7         3.3        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   8         3.7        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   9        10.5         58   0   0   4   4   4  13   0   4   4   8   0   0   0   0   0   0   0
  10         8.1         71   0   8   0   0  13   8   0   0   0   0   0   0   0   0   0   0   0
  11         8.3         63   0  21   4   4   0   8   0   0   0   0   0   0   0   0   0   0   0
  12        20.8          0   0   4   0   0  13  13  13  13  25   8   8   4   0   0   0   0   0
  13         8.0         83   0   0   0   0   0   0   4   8   0   4   0   0   0   0   0   0   0

WKLY AVG=>  9.0          68   0   5   1   1   4   6   2   4   4   3   1   1   0   0   0   0   0

  14         4.1        100   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  15       *10.5 13 HRS  46   0   8   8  15  15   8   0   0   0   0   0   0   0   0   0   0   0
  16        NO DATA
  17        NO DATA
  18        NO DATA
  19        NO DATA
  20        NO DATA

WKLY AVG=>  7.3          81   0   3   3   5   5   3   0   0   0   0   0   0   0   0   0   0   0

----------------------------------------------------------------------------------------------------
 DEC         8.7         72   1   3   3   3   4   4   2   2   3   2   1   1   1   0   0   0   0

NOTE:  * INDICATES THAT A DAILY AVERAGE IS FOR FEWER
         THAN 24 HOURS.  THE TOTAL NUMBER OF HOURS IS GIVEN.
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